AIRCRAFT ENGINES

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PREFACE

This book, written especially for the enlisted men of Naval Aviation, is designed to furnish them with the information necessary to the performance of their aviation duties.

A knowledge of aircraft engines is of primary importance to Aviation Machinist's Mates. Beginning with the basic principles of engine operation, this book furnishes general information on all types of powerplants. Then the text becomes specific, and provides descriptions of the outstanding aircraft engines used in Naval Aviation.

As one of the Navy Training Courses, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Division of the Bureau of Naval Personnel.

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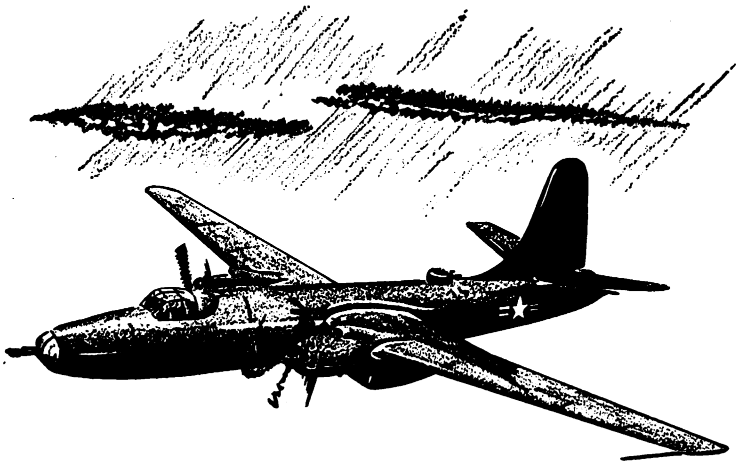
AIRCRAFT ENGINES



CHAPTER 1

POWER

More than 40 years of aviation progress have brought about great changes in aircraft engines. The power plant of a modern airplane bears little resemblance to those installed in aircraft at the turn of the century. The simple installation that powered the Wright brothers' plane at Kitty Hawk has given way to engines capable of driving airplanes at speeds beyond that of sound.

Early aircraft engines were primarily liquid-cooled. Before and during World War I, however, a trend developed among French aeronautical engineers toward air-cooled engines. The famous Liberty engine, considered a great accomplishment because it weighed only 2.02 pounds per developed horsepower, was a product of this period.

Although American manufacturers clung to liquid-cooled engines, the Navy, about 1920, began installing the air-cooled types in its aircraft. You will observe that today there are practically no liquid-cooled engines in Naval Aviation, and those retained are either obsolete or experimental.

TYPES OF ENGINES

There are two general types of internal-combustion engines used in naval aircraft. These are the RECIPROCATING type and the TURBO–JET type. The latter derives its name from the fact that it contains a gas turbine, and ejects its exhaust in jet form.

Structurally, the reciprocating-type engine is further divided

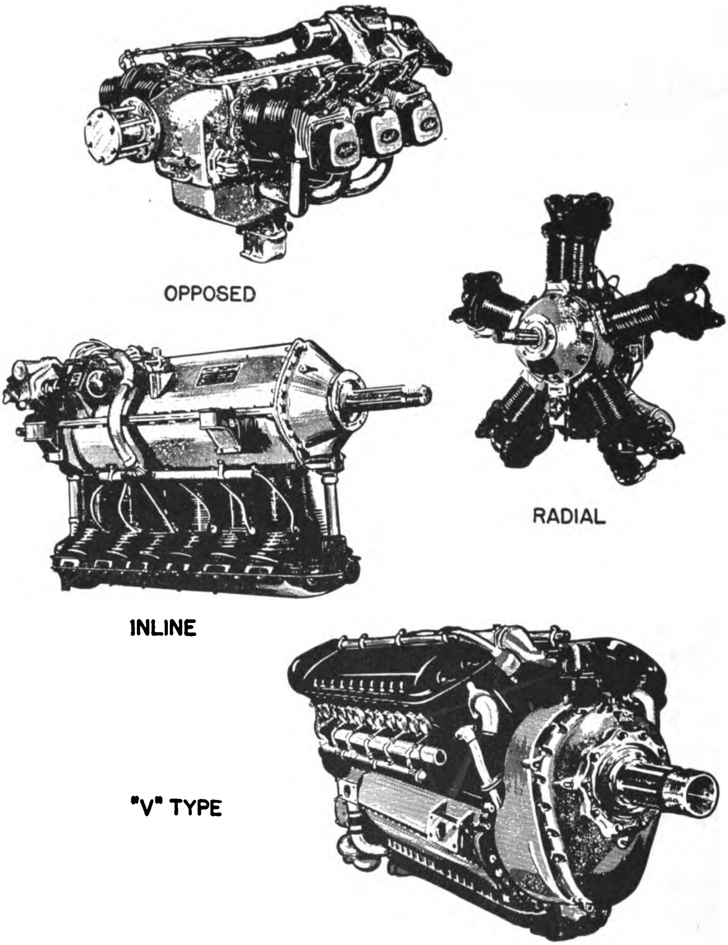


Figure 1.—Reciprocating engine types.

into the in-line and radial types. These designations stem from the cylinder arrangement of each type.

IN–LINE ENGINES have cylinders arranged in a straight line in the engine block. Among in-line engine types are the VERTICAL, the OPPOSED, and the V, the types again symbolizing cylinder arrangement. Generally, in-line engines have been developed as liquid-cooled powerplants, although a few air-cooled in-line engines have been used.

RADIAL ENGINES are built with cylinders evenly distributed around the crankcase in one, two, or more banks. As a rule, these engines have from seven to nine cylinders arranged in a circular row, or as many as 28 in four rows of 7 each. Today, the majority of engines used in aircraft are of the radial type.

The latest development of the aircraft powerplant is the TURBO–JET ENGINE, also air-cooled. Although classified as an internal-combustion engine, the turbo-jet is a distinct departure from the conventional aircraft powerplant. It is so constructed that the thrust produced by combustion is utilized directly without the use of a propeller or any form of mechanical linkage.

Before you delve too deeply into engine design, it might be a good idea to review the principles of engine operation and brush-up on a few of the terms so closely associated with your daily work as an Aviation Machinist's Mate.

Since the first part of this book deals with reciprocating engines ("reciprocating" refers to the alternate back-and-forth movement of the piston), the discussion in this chapter will be confined to that type of engine.

WORK AND POWER

Work doesn't mean simply applying a force. Work, in the mechanical sense of the term, is done only when a RESISTANCE IS OVERCOME BY A FORCE ACTING THROUGH A MEASUREABLE DISTANCE. Notice that two factors are involved—FORCE and MOVEMENT THROUGH A DISTANCE. The force is normally measured in pounds and the distance in feet. Work, therefore, is commonly measured in a unit called FOOT-POUND (abbreviated ft.-lb.). Thus, if you lift a 100-pound weight through a ver-

tical distance of 3 feet, you have performed 300 (3×100) foot-pounds of work.

Power is the RATE of doing work and is expressed as work per unit of time. If it takes you 1 second to lift the 100-pound weight a distance of 3 feet you have exerted 300 ft.-lbs. per second of power. If it takes your buddy 4 seconds to lift the same weight the same distance, he has only exerted 75 ft.-lbs. per second of power $\left(\frac{300 \text{ ft.-lbs.}}{4 \text{ sec.}}\right)$. That rates you, in this instance, four times more "powerful," even though he has done the same amount of work.

The common unit of mechanical power is HORSEPOWER, abbreviated hp. Late in the eighteenth century, Watt defined one hp. as the power required to lift a weight of 33,000 pounds to a height of 1 foot in 1 minute of time, or 33,000 ft.-lbs. per minute. To reduce this to seconds, simply divide by 60, and you get 550 ft.-lbs. per second.

Remember, work is the product of a force and a distance, and power is work per unit of time. Consequently, if you lifted one pound to a height of 33,000 feet in 1 minute, the work performed would be 33,000 ft.-lbs. and the power exerted would be 33,000 ft.-lbs. per minute, or one hp.

Don't form the mistaken idea that work is done only when a force is applied for lifting, for the force may be exerted in any direction. Let us suppose that you drag the 100-pound weight along the ground. You are still exerting a force, although its line of action is approximately horizontal. The amount of force required to drag the 100-pound weight would depend on the smoothness of the ground.

If you were to fasten a spring scale graduated in pounds to the weight, and then to drag it by pulling on the handle of the scale, you could determine the pounds of force applied. If you exerted 80 pounds, and dragged the weight 660 feet in 2 minutes, you will have performed 52,800 ft.-lbs. of work in 2 minutes (80×660), or 26,400 ft.-lbs. each minute. Since a horsepower represents 33,000 ft.-lbs. per minute, you will have expended $\frac{26{,}400}{33{,}000} = 0.8$ hp.

Now let us see how all this applies to aircraft. You know

that the air is constantly tending to hold back an airplane in flight, and that this resistance must be overcome as the airplane flies. Let's say, for example, that an airplane is moving at the rate of 220 feet per second, which is 150 miles per hour (m.p.h.), and that the total resistance of the air is equal to 250 pounds. How much power is required to keep the airplane moving at this speed?

The work per second is 250×220, or 55,000 ft.-lbs. Since one hp. is 550 ft.-lbs. per second, you divide 55,000 by 550, and get an answer of 100 hp. This, then, is the horsepower required to fly an airplane at a speed of 150 m.p.h. when the resistance is 250 pounds.

ENERGY INTO WORK

The amount of this power required to spin an airplane propeller is obtained by harnessing the energy created by combustion, which is simply burning (although technically it means the uniting of fuel and oxygen). This process is accompanied by the generation of heat, and heat is a form of energy which may be converted into work.

Gasoline has greater heat energy per pound than any other common substance, thus making it an ideal fuel for airplane engines. The oxygen needed for combustion is supplied by the air—about 15 pounds of air for each pound of fuel is the ratio required by an airplane engine.

To understand how an airplane engine operates, there are two simple laws of physics that must be considered.

First, if the temperature of a confined gas is not changed, the pressure will increase inversely as the volume is decreased. Conversely, the pressure will decrease inversely as the volume is increased. That principle is known as BOYLE'S LAW. A simple demonstration of how this law works may be made with a toy balloon. If you squeeze the balloon, its volume is reduced and the pressure of air inside the balloon is increased. If you squeeze hard enough, the pressure will burst the balloon.

Second, if a gas under constant pressure is so confined that it may expand, an increase in the temperature will cause an increase in volume. This is CHARLES' LAW. If you hold the

inflated balloon over a stove, the increase in temperature will cause the air to expand and, if the heat is sufficiently great, the balloon will burst. Thus the heat of combustion expands the gas in an engine cylinder.

There you have the basic principles of aircraft engine operation. An engine is actually a DEVICE FOR CONVERTING HEAT ENERGY INTO MECHANICAL WORK.

Briefly, here's how the conventional reciprocating, internal-combustion engine operates. Gasoline is mixed with air, and the mixture is forced or drawn into a cylinder, compressed by a piston, and then ignited by an electric spark. The conversion of the heat energy of the fuel into work is accomplished within the cylinder. Figure 2 illustrates the various compo-

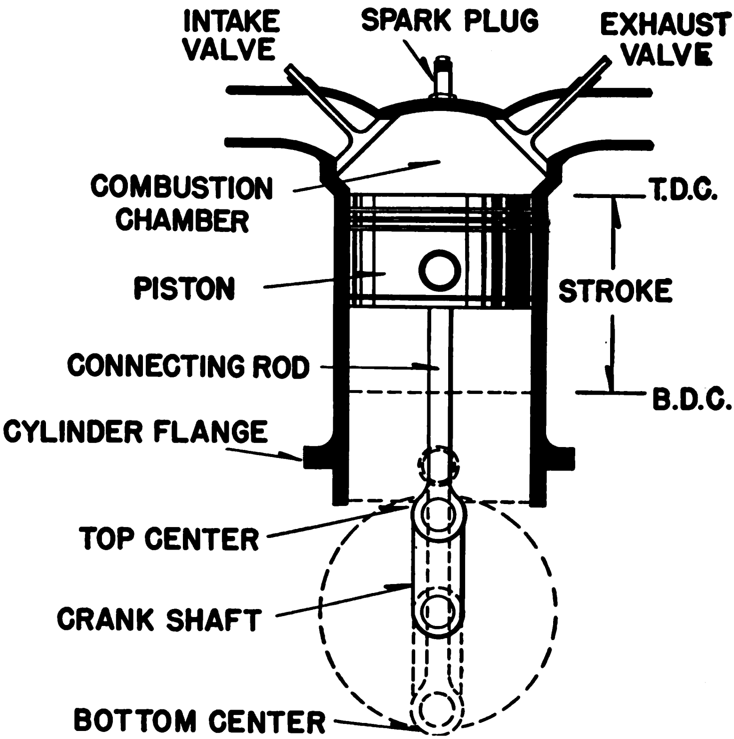


Figure 2.—Components and terminology of engine operation.

nents acting together to accomplish this conversion, and also presents the principal terms used to indicate engine operation.

When the compressed mixture is ignited, the resultant gases of combustion expand very rapidly and force the piston to move away from the end of the cylinder. This downward motion of the piston, acting on the crankshaft through the connecting rod, is converted into a circular or rotary motion by the crankshaft. The rotating crankshaft spins the propeller. The momentum of the crankshaft and propeller also forces the piston back up toward the end of the cylinder where it is ready for the next cycle.

A valve in the top (head) of the cylinder opens to allow the burned gases to escape, then closes while another valve opens to let in a fresh fuel-air mixture. The valve allowing for escape of burned gases is called the EXHAUST VALVE, and the valve letting in the new mixture is known as the INLET or INTAKE VALVE.

These valves are opened and closed at the proper time by a system of gears and cams.

FOUR-STROKE CYCLE

Each complete movement of the piston in one direction is called a STROKE. The series of events occurring between the entrance of a charge of fuel-air mixture and the exhaust of the burned gases is termed a CYCLE.

Most aircraft engines are of the four-stroke cycle type in which each piston makes four strokes during a complete cycle. In figure 3 is shown the basic operations involved in a four-stroke cycle engine.

Assuming that the engine under discussion is now operating, let's look at view (A) of figure 3. The piston illustrated is moving downward—or toward the crankshaft—as a charge of combustible mixture is forced into the cylinder through the intake valve opening. This stroke is the INTAKE STROKE.

In view (B) of figure 3, the piston has passed its lowest point (bottom dead center) and is moving upward, or away from the crankshaft. The charge is being compressed, hence

the term COMPRESSION STROKE. During this stroke, both intake and exhaust valves are closed.

Shortly before the piston reaches the top of the compression stroke, a spark is produced across the points of the spark plug, igniting the compressed mixture. Because this ignition occurs just before the piston reaches its top position (top dead center), the pressure produced by combustion is utilized most effectively.

The hot gases produced by combustion create tremendous pressure on the piston, forcing it to move downward again. This is demonstrated in view (C) of figure 3, and is called the POWER STROKE. Near the end of this stroke, the exhaust valve opens and the gases begin flowing out of the cylinder.

The moving crankshaft causes the piston to return upward once again, as illustrated in view (D) of figure 3. During this EXHAUST STROKE, the remaining gases are forced out of the cylinder.

Note that for each complete cycle of operation, the piston makes two trips up and two trips down. For each up and down motion, the crankshaft makes two complete revolutions for each four-stroke cycle. Since all the pistons in an engine are connected to the same crankshaft—this holds true regardless of the number of cylinders—each cylinder in an engine fires once for each two revolutions of the crankshaft.

The power strokes in the various cylinders are timed to give consecutive "pushes" at equal intervals so as to keep the crankshaft turning with a minimum of vibration.

In actual engine operation, a number of varying conditions control engine efficiency. These conditions are governed by the following rules:

As the weight of properly proportioned vaporized fuel-air mixture admitted into an engine cylinder increases, the power increases, provided the charge is not compressed above the critical pressure for the fuel. The critical pressure of a fuel is the pressure at which the vaporized fuel-air mixture will detonate at normal engine-operating temperatures. Normally, engine fuel mixtures burn outward at an even rate from the ignition spark or sparks. Detonation is a too-rapid burning or explosion of the last quarter (approximately) of the com-

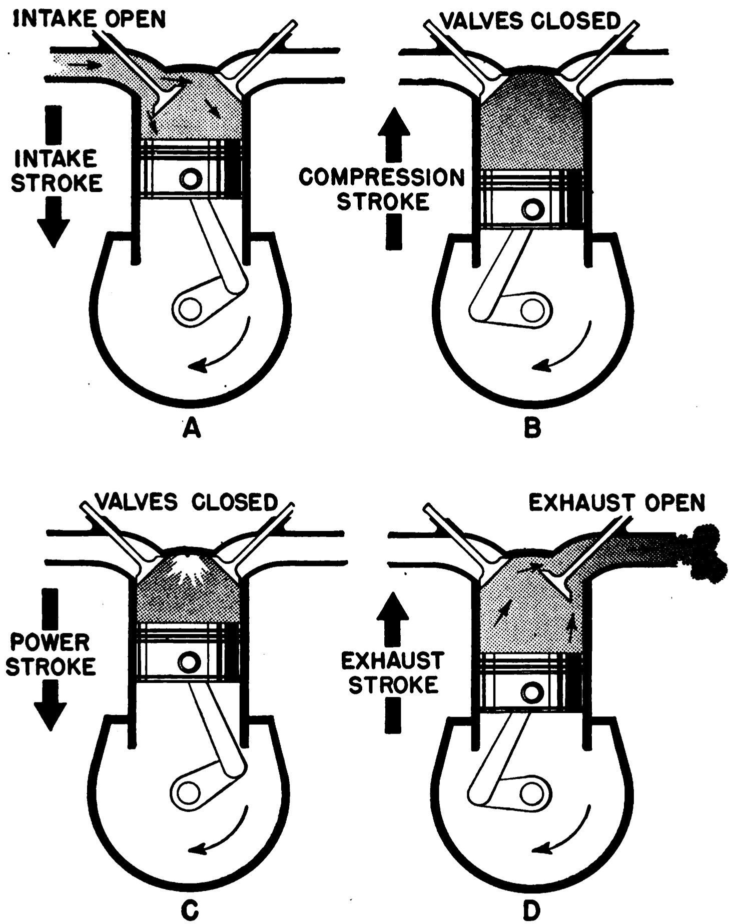


Figure 3.—Four-stroke cycle.

bustible material. It takes place when the pressure in the cylinder increases beyond the prescribed limits for the fuel. As the percentage of exhaust gases scavenged from the cylinder is increased, the volume available for the intake charge is increased, and consequently more power may be developed.

By opening the intake valve before the piston reaches top center on the exhaust stroke, more fuel-air mixture is ad-

mitted into the cylinder at normal operating speeds. This timing results in poor efficiency at low speeds. However, the sacrifice is well worth the gain at normal operating speeds. By allowing the intake valve to remain open during a part of the compression stroke, the charge of fuel-air mixture is further increased. Actually, the intake valve is open during part of the exhaust stroke, all of the intake stroke, and part of the compression stroke.

The exhaust valve opens when the piston is approximately two-thirds down the power stroke. This not only aids in removing burned gases, but results in more efficient cooling of the cylinders. By allowing the exhaust valve to remain open during the last part of the power stroke, the full length of the exhaust stroke, and the first part of the intake stroke, practically all of the burned gases are expelled from the cylinder.

The igniting of the fuel charge is a vital element in the operation of a conventional aircraft engine, and must take place at exactly the proper time. The ignition system is therefore timed to ignite the charge before the piston reaches top dead center on the compression stroke in order to allow sufficient time for the burning charge to reach its maximum pressure at the instant the piston passes top dead center.

Because the rate of burning is affected by the compression of the charge—and the compression of the charge is governed largely by the weight of the fuel-air mixture admitted into the cylinder—the time at which the charge is ignited should vary with the throttle setting in order to obtain maximum efficiency at all engine speeds.

TWO-STROKE CYCLE

Many of the auxiliary powerplants for the big flying boats are of the two-stroke cycle type. In this type of powerplant, the valves are arranged differently, and only two strokes (one upward and one downward) are necessary to make a complete cycle. This is illustrated in figure 4.

The crankcase intake and cylinder compression strokes are combined in the upward movement of the piston. The crankshaft makes one revolution for each complete cycle. All cylinders fire once for every revolution of the crankshaft.

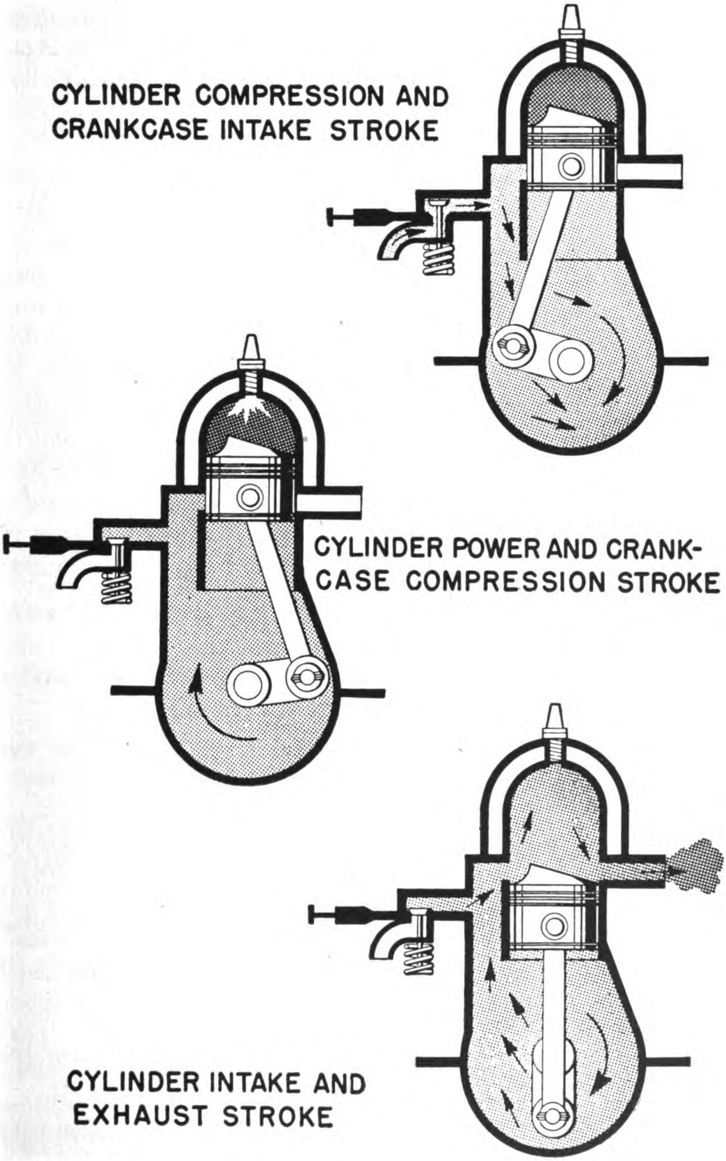


Figure 4.—Two-stroke cycle.

In a conventional aircraft engine, the fuel-air mixture must be compressed to attain efficient combustion and produce maximum pressure. If the charge is ignited at atmospheric pressure, combustion is slow and the pressure or power produced is relatively low.

An engine that compresses the charge to 100 pounds per square inch (p.s.i.) will develop approximately one horsepower for every four cubic inches displaced by the piston.

By compressing the charge to 140 p.s.i., one hp. of work may be produced by approximately 1.8 cubic inches of piston displacement. In general, the power and efficiency of an internal-combustion engine increases proportionately with compression. However, compression pressures are limited by the fuel used and the service for which the engine is intended. Extremely high compression results in premature firing (detonation) and sets up heavy stresses in the structural parts of the engine.

Up to certain critical limits, the effects of compression in increasing the efficiency and output of an engine are twofold:

1. Compression produces heat which aids in the vaporization of the fuel.
2. At the point of maximum compression, the smaller volume of gas leads to more effective burning.

The compression obtained in any cylinder is affected by the following factors:

1. The ratio of the total volume of the cylinder to the compression space, or the COMPRESSION RATIO. (In a cylinder having a piston displacement of 80 cubic inches and a combustion chamber space of 20 cubic inches, the compression ratio is $\frac{80+20}{20} = 5$, or, as it more commonly appears, 5:1.)
2. The pressure of the charge in the cylinder when the compression process begins.

The compression pressure in the cylinder varies directly with the initial pressure of the charge at the beginning of the compression stroke. The initial pressure is determined by the

volume and density of the charge admitted to the cylinder, or the VOLUMETRIC EFFICIENCY of the cylinder.

Volumetric efficiency is the ratio of the volume of the fuel-air charge admitted into the engine cylinder at atmospheric pressure and temperature to the piston displacement, and is expressed as a percentage. For example, a volume of 95 cubic inches of fuel-air mixture admitted into a cylinder of 100 cubic inch displacement has a volumetric efficiency of 95 percent. $\left(\frac{95}{100} = 0.95 = 95 \text{ percent}\right)$.

Through the use of superchargers, volumetric efficiency may be increased higher than 100 percent because the charge is forced into the cylinder at pressures above atmospheric. Thus, the higher the manifold pressure readings of an aircraft engine in operation, the higher the compression pressure of the charge and the greater the power output.

HORSEPOWER CALCULATIONS

There are a number of factors that affect the horsepower which any reciprocating, internal-combustion engine may produce. These are the bore, the stroke, the mean effective pressure, the number of revolutions per minute, and other factors such as friction and volumetric efficiency.

BORE means the inside diameter of the cylinder. Increasing the bore will increase the quantity of fuel and air that can be contained in the cylinder.

By STROKE is meant the total distance that the piston moves in one direction, or the length of its movement from top dead center to bottom dead center. Increasing the stroke also increases the amount of fuel and air that can be admitted into the cylinder.

MEAN EFFECTIVE PRESSURE (usually abbreviated m.e.p.) indicates the average pressure in pounds per square inch inside the cylinder during the power stroke. The m.e.p. is naturally determined to a large extent by the compression ratio. The m.e.p. can be measured by a pressure gage or indicator installed by connections leading into the combustion chamber. The pressure in the cylinder varies from a maximum shortly after combustion to a minimum near the bottom of the stroke.

REVOLUTIONS PER MINUTE affect the horsepower. Obviously, as the number of power impulses is increased, more power is produced.

There are other factors that affect the horsepower to some extent, although their effect in many instances is difficult to calculate. Among these factors are the shape of the combustion chamber, the air temperature, barometric pressure, humidity, and the friction of the various moving parts of the engine.

INDICATED HORSEPOWER (i.hp.) of a four-stroke cycle engine can be calculated by the following formula—the word PLANK is used for ease in remembering this formula.

$$\frac{\text{PLANK}}{33{,}000} = \text{i.hp.}$$

P denotes mean effective pressure in pounds per square (p.s.i.).

L indicates the length of the stroke in feet or fractions of a foot.

A is the area of the piston head, or the cross-section of the cylinder, in square inches.

N represents the number of power strokes per minute per cylinder $\left(\frac{\text{rpm}}{2}\right)$.

K denotes the number of cylinders.

No difficulty should be experienced in understanding how horsepower is calculated by this formula. The area of the piston times the pressure per square inch gives the force on the piston in pounds. This force multiplied by the length of the stroke in feet or fractions thereof gives the work performed in one power stroke. By multiplying the amount of work done in one power stroke by the number of strokes per minute, you get the number of ft.-lbs. per minute for one cylinder. Multiplying this by the number of cylinders gives the total number of ft.-lbs. per minute for the engine. Since one horsepower is 33,000 ft.-lbs. per minute, the total number of ft.-lbs. is divided by 33,000 to find how many horsepower are being produced. This is indicated horsepower.

Brake horsepower (b.hp.) is the power available for actual use in spinning the propeller. This may be determined by a device known as a prony brake which, in its simplest form, is a brake applied to a drum rotated by the crankshaft. By measuring the force on the end of an arm attached to the brake, the actual (effective) horsepower being produced by the engine can be determined. Brake horsepower may also be determined by a dynamometer or a calibrated club propeller.

Friction horsepower (f.hp.) is the horsepower expended in overcoming the friction of the moving parts; in drawing in the charge and expelling the burned gases; and in driving the accessories, oil pumps, etc. Friction horsepower is the difference between indicated horsepower and brake horsepower. If any two of these three horsepowers are known, the third may be calculated by using the following formula:

$$\text{b.hp.} = \text{i.hp.} - \text{f.hp.}$$

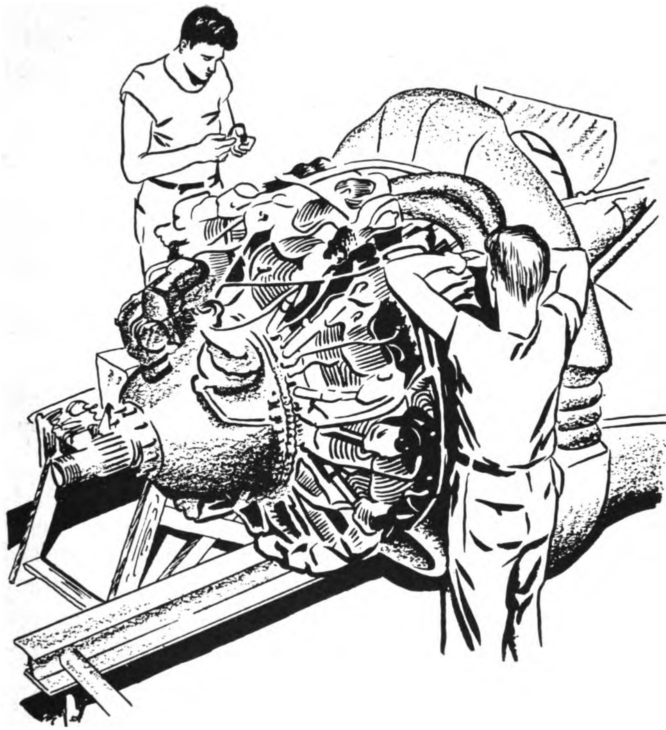
Brake mean effective pressure (b.m.e.p.) is another term used in connection with horsepower. It is the theoretical mean effective pressure which would produce the actual brake horsepower if frictional losses were not present.

Maximum power is the greatest power the engine is capable of producing under any circumstances. In most cases, it is permissible to use the maximum power for a short period of time only, usually one to five minutes in taking-off.

Rated power is the power guaranteed by the manufacturer for a given r.p.m.

QUIZ

1. What two general types of internal combustion engines are used in naval aircraft today?
2. How is power expressed?
3. What is the common unit of mechanical power?
4. If a jeep pulls with a constant force of 900 pounds in hauling a truck up a hill one-half mile long, how many foot-pounds of work will it perform?
5. If the jeep is traveling at the rate of four m.p.h., how much power does it exert in pulling the load?
6. A pressure gage indicates the m.e.p. of a 14-cylinder four-stroke cycle engine running at 2,000 r.p.m. to be 90 p.s.i.; the length of the piston stroke is 0.4 feet; and the area of the piston head is 6 square inches. What is the indicated horsepower for this engine?
7. In a four-stroke cycle engine, when does the exhaust valve open?
8. When is the fuel-air mixture in the cylinder ignited?
9. In the two-stroke cycle engine, how many complete revolutions does the crankshaft make for each cycle?
10. What is the compression ratio of an engine that has cylinders with a piston displacement of 120 cubic inches and a compression space of 20 cubic inches?



CHAPTER 2

ENGINE PARTS

Reliability of an aircraft engine is of major importance, and the major problem in the development of such a powerplant is to effect a design insuring both strength and lightness while retaining reliability.

All moving parts of an aircraft engine must be accurately machined and balanced in order to reduce vibration and fatigue to a minimum. Every detail must be worked out to obtain an engine that has good design, is light in weight per horsepower, and is comparatively economical in fuel and oil consumption.

An engine is constructed of both moving and stationary parts. The moving parts include the pistons, master rod and

link rod assemblies, crankshaft, valves, valve-operating mechanisms, reduction gears, accessory drives, and superchargers. The stationary parts include the cylinders, engine sections, and the assemblies used with each.

CYLINDERS

The cylinder acts as a guide for the piston and forms the fixed wall of the combustion chamber. It is that part of the engine in which the power to accomplish work is developed. We will see that the cylinder, its piston and connecting rod, and the crankcase form the power section of the engine.

Cylinders perform a twofold function. They provide a combustion chamber for the burning and expansion of gases, and they house the piston and connecting rod.

Cylinders designed for aircraft engines are of the I or overhead valve type, as shown in figure 5. They are divided into two parts—the barrel and the head. The head is screwed and shrunk onto the barrel to form a semi-permanent joint.

Cylinder barrels are machined from steel forgings (formed by heating and hammering) or centrifugal castings (formed in molds). The inner surface is hardened to resist the wear of the piston and piston rings bearing against it. Cylinder hold-down flanges are provided for mounting the cylinder to the crankcase by studs and nuts and/or cap screws.

When the cylinder is installed, the portion of the cylinder barrel below the hold-down flange extends into the crankcase. This decreases the overall diameter of the engine without sacrificing length of stroke, and provides for a very rigid mounting of the cylinder.

Some cylinders are fitted with aluminum alloy muffs or sleeves in which deep-cut cooling fins are machined. Other cylinders are fitted with fabricated aluminum alloy sheetmetal cooling fins.

Cylinder heads are machined from aluminum alloy castings or forgings. They have closely-spaced cooling fins and two integral rocker boxes (housings). Forged heads withstand greater pressures and have greater heat conductivity than cast heads because of their increased density. Provisions are made

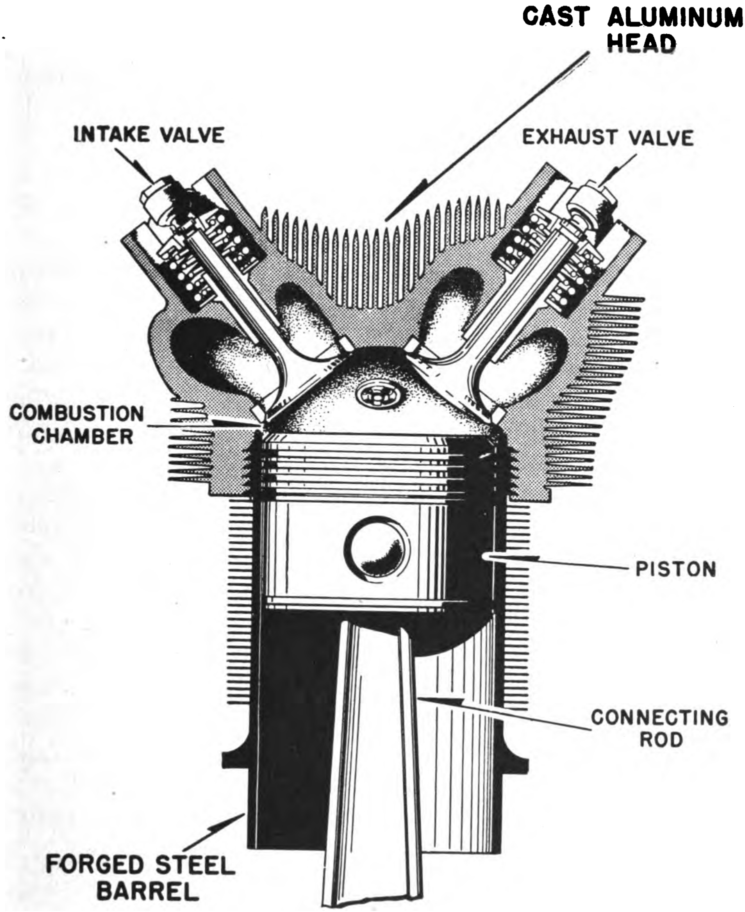


Figure 5.—Cylinder cutaway.

in the cylinder head for the installation of two valves—an intake and an exhaust—and two spark plugs. The head also has an intake port and an exhaust port to which, respectively, are attached an intake pipe and an exhaust pipe.

VALVES

Cylinder valves, as you have seen, open and close the passageways which admit the fuel-air mixture into the cylinder

and release the exhaust gases. Two valves are used—intake and exhaust.

Valves used in aircraft engine cylinders are of the conventional poppet type, as illustrated in figure 6. As to shape, the three most common types of poppet valves are the tulip, the semi-tulip, and the mushroom. Valves are usually made of chrome-nickel steel or tungsten steel alloy. Both metals retain their strengths at relatively high temperatures.

The HEAD of the valve is that part which opens and closes the passageways. It has a ground face which rests on the valve seat in the cylinder when in a closed position. A thin layer of stellite or other heat-resisting metal, fused to the valve face, greatly retards corrosion, pitting, and warping. This

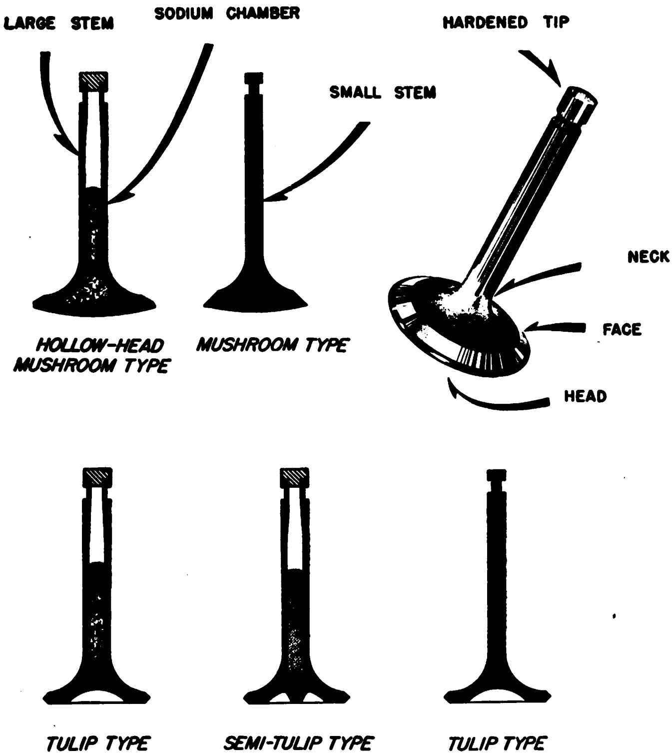


Figure 6.—Valves.

heat-resisting layer is particularly desirable for exhaust valves. The stem of the valve also may be tipped with stellite to reduce wear at the rocker-arm contact.

The STEM of a valve acts as a pilot for the valve head when the valve is operating. The guide for the valve stem is located in the cylinder head. Those exhaust valve stems which are hollow are filled with metallic sodium to reduce the temperature of the operating valve head. The heat in the valve is conducted away from the valve head and out along the stem, from which it is dissipated.

Most intake valves have a tulip- or a semi-tulip-type head and a smaller stem than that of the exhaust valves. Since the intake valve is cooled by the fuel-air mixture from the carburetor, a large stem is not required for heat dissipation.

Exhaust valves have heavier heads and stems of greater diameter than intake valves. This greater weight and larger size aids the exhaust valve in withstanding the high temperature at which it operates. Most exhaust valve heads are hollow and partly filled with metallic sodium.

Metallic sodium is an excellent conductor of heat. Having about six times the heat conductivity of steel, it melts at approximately 208 degrees Fahrenheit. The reciprocating movement of the valve circulates the liquid sodium, which in turn carries heat away from the valve head to the valve stem where it is dissipated through the valve guide to the cylinder head and cooling fins. The temperature of the operating valve filled with metallic sodium is thus lowered 300° to 400°.

This decrease in temperature of metallic sodium filled exhaust valves gives a temperature of 900° to 1,000° for exhaust valves in normal operation.

VALVE–OPERATING MECHANISM

The valve-operating mechanism of an engine consists of those parts opening and closing the valves at the proper time in relation to crankshaft position. The mechanism of a single-row radial engine will serve to illustrate the functions of the individual components.

The CAM RING OR CAM DRUM is located in the nose section of

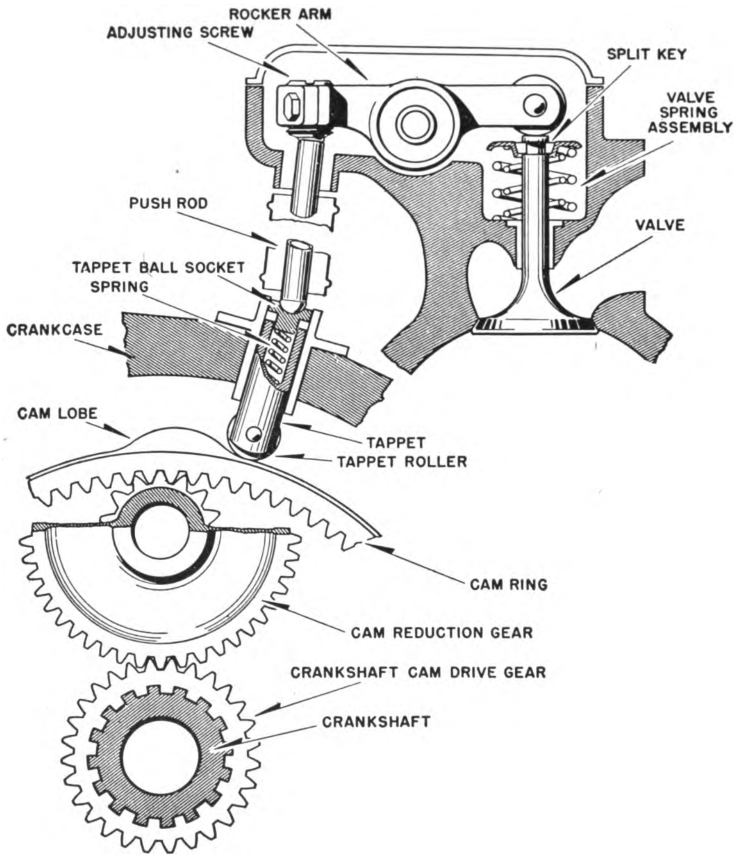


Figure 7.—Valve-operating mechanism.

the crankcase and is driven indirectly by the crankshaft through a cam drive gear, as demonstrated in figure 7. The cam has lobes spaced on its outer surface to govern the "lift" or distance the valve opens and the degrees of crankshaft travel through which it remains open.

The CAM FOLLOWER assembly, consisting of a roller, or wheel, and a tappet, is mounted in a tappet guide. The action of the cam follower is similar to that of the front wheel and fork of a bicycle. Both the cam follower roller and the bicycle wheel

follow the contour of the path over which they travel, following each rise or descent as it is encountered. Thus, the cam follower assembly converts the cam lobe contour into up-and-down (reciprocating) motion.

A PUSH ROD, constructed of hollow tubing with hardened steel ball ends, transmits the motion of the cam-follower to the rocker arm.

The ROCKER ARM is mounted on a bearing in the rocker box, and transmits the motion of the push rod to the valve. This arm is equipped with an adjusting screw which provides for adjustment of valve clearance. This valve clearance compensates for heat expansion.

The function of the foregoing units is to open the valve and hold it open for the required travel of the crankshaft and piston.

The VALVE SPRING ASSEMBLY consists of two or more valve springs, the necessary valve spring retaining washers, and the locking devices for securing the spring assembly to the valve. These locking devices are known as keepers or split keys, and are generally made in the form of a split cone. The function of the valve spring assembly is to close the valve and hold it securely on the valve seat. Multiple springs are used to neutralize the vibration by mutual absorption.

A twin-row radial engine has two cams. The one located in the nose section operates the valves of the front row of cylinders. The other, located in the rear section of the crankcase, operates the valves in the rear row of cylinders.

Most cams have two rows of cam lobes. One row operates the intake valves in a row of cylinders, and the other row of lobes operates the exhaust valves in the same row of cylinders. Some engines have more than one cam per row of cylinders. The R-4360, for example, has five identical cams.

The operation of the valve mechanism may be summed up as follows: The cam lobes acting on the cam follower assembly actuate the push rods which in turn operate the rocker arms which open the valves. The valve springs act to close and hold the valves securely on the valve seats.

PISTONS

The piston acts as the moving wall of the combustion chamber. It helps to produce a pressure differential between the displacement space and the intake manifold as the fuel-air mixture is admitted into the cylinder.

After the fuel-air mixture has been admitted to the cylinder, the piston compresses the mixture, transmits the work accomplished by combustion to the crankshaft, and forces the burned gases from the cylinders. The piston must have sufficient strength to withstand the combustion pressures while still being as light as possible to keep down inertial forces. When you realize that a piston may make more than 5,000 starts and stops in one minute at take-off speed, you can understand the importance of light yet sturdy construction.

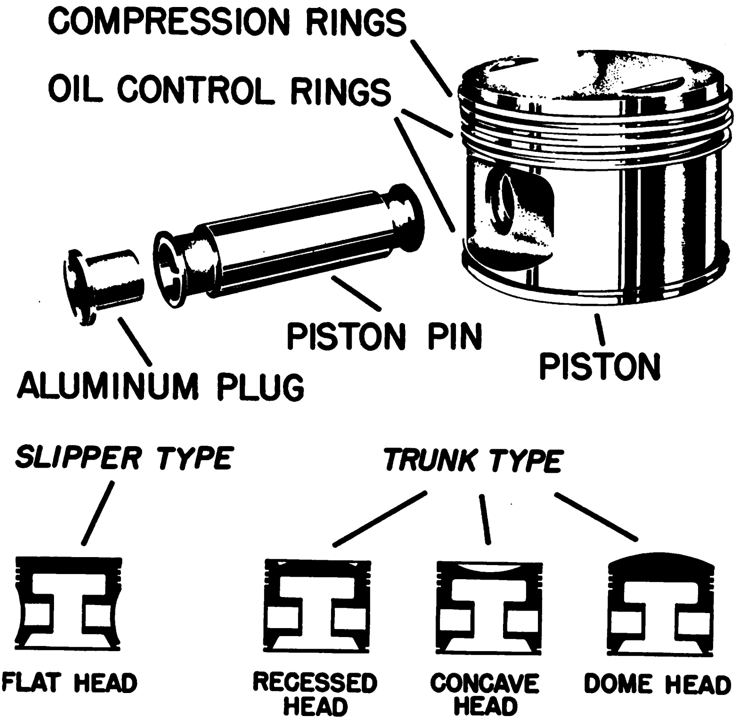


Figure 8.—Piston assembly and types of pistons.

The top of the piston is called the HEAD, while the sides are known as the SKIRT.

The majority of aircraft engine pistons are manufactured from aluminum alloy. Pistons constructed of aluminum alloy forgings reduce operating stresses to a minimum and rapidly conduct heat away from the piston head to adjoining engine parts for radiation. This results in a comparatively low operating temperature for the piston and consequently a low heat transfer to the incoming charge during the intake stroke. A typical piston assembly diagram is presented in figure 8.

Pistons are classified as to shape of skirt, and from this classification we have the TRUNK type and the SLIPPER type.

The piston head may be flat, convex, or concave. Recesses are machined in some flathead pistons used in high-compression engines to permit the valves to open without interference. The inside of the head is usually ribbed for strength and for the purpose of increasing surface area for heat dissipation.

There may be as many as six grooves around the piston to accommodate the compression rings and oil control rings. The latter are drilled through at several points to allow surplus oil scraped from the cylinder wall to be forced into the crankcase by the oil control ring. A groove in the piston skirt, below the piston pin, accommodates an oil scraper ring to prevent excessive oil consumption.

The sidewalls (skirt) of the piston act as guides or bearing surfaces for the head, and incorporate the piston pin bosses. These are of heavy construction, and usually are ribbed to carry the piston pin load.

Piston rings prevent leakage of gas pressure from the combustion chamber and reduce to a minimum the seepage of oil into the combustion chamber. The rings fit into the grooves of the piston but spring out to make contact with the cylinder walls and, when properly lubricated, form a gas seal. They must be capable of exerting sufficient spring pressure against the cylinder wall to perform their function with a minimum of friction.

Most piston rings are made of high grade cast iron. They are of uniform thickness, and a cross section is either rectangular or wedge-shaped. The gap in the piston ring, where

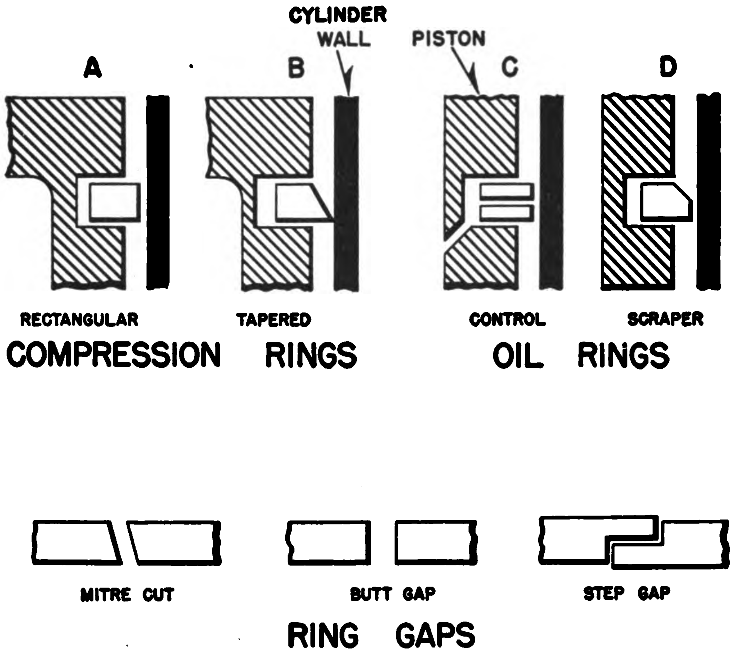


Figure 9.—Cross section of piston rings.

it butts together in position in the cylinder, may be diagonal, step, or butt cut. Only a small amount of seepage occurs at the gap, regardless of the shape of the cut. The gaps are staggered (not in line) when the rings are installed.

The oil control ring is generally similar in construction to a compression ring. Some manufacturers, however, use two thin rings as shown in view (C) of figure 9. These rings are milled out at intervals on the lower side to permit surplus oil from the cylinder wall to seep freely back into the crankcase through the drilled holes in the groove.

An oil scraper ring, beveled on its outside circumference, is shown in (D) of figure 9. Modern types of compression rings are similar to oil scraper rings, but with only a slight bevel, as shown in (B) of figure 9.

The PISTON PIN connects the piston assembly to the connecting rod, and is machined from a nickel-steel alloy forging,

case hardened and ground. A piston pin is sometimes called a wrist pin. Let's look again at the piston pin in figure 8. This pin is made hollow for lightness. The type used in aircraft pistons is free to move in bearings in the piston and in the small end of the connecting rod. It is known as the full-floating type.

A piston pin may be held in place by aluminum plugs or spring locks which prevent it from scoring the cylinder walls.

CONNECTING ROD

The connecting rod is the link between the piston and the crankshaft. It transmits the power of combustion from the piston to the crankshaft, thus converting the up and down (reciprocating) motion of the piston into a rotary motion at the crankshaft.

The type of connecting rod used depends on the cylinder arrangement of the engine. The conventional radial aircraft engine is fitted with one master connecting rod, usually called a MASTER ROD, to which is fastened one ARTICULATED or LINK ROD for each of the other cylinders in that particular row.

The master rod may be constructed in either one or two pieces, depending upon the construction of the crankshaft. Crankshafts constructed in a single piece require a split-type master rod, and a crankshaft built in two or more pieces uses a single-piece master rod.

The articulated or link rods are secured to the master rod by means of knuckle pins and to the piston by means of piston pins. The connecting rods are forged from chrome-nickel steel alloy similar to that used for crankshafts.

CRANKSHAFT ASSEMBLIES

The crankshaft of the engine receives the power developed in the cylinder and delivers it to the propeller. In other words, it converts the power stroke of the pistons into rotary motion which turns the propeller.

This unit is a shaft composed of one or more cranks located at definite places between the ends.

Crankshafts are made of alloy steel. In some engines they

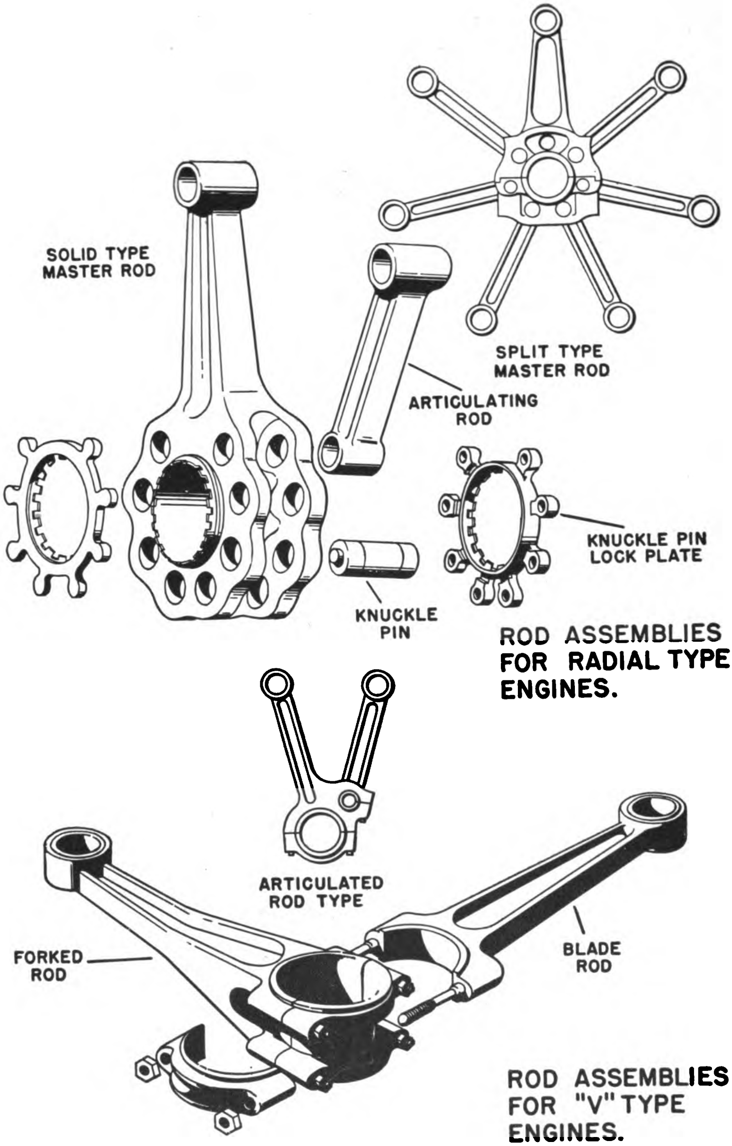


Figure 10.—Master rod assembly.

are formed of two or more pieces, while in others they are made of a single drop forging. They are machined accurately to shape and final size. Crankshafts must be hollow to permit proper distribution of lubricating oil.

The forward end of the crankshaft may be either splined or tapered, depending on the type of propeller with which the engine is fitted.

The offset in the crankshaft is referred to as the THROW. Thus, a crankshaft for a twin-row radial engine with cylinders arranged in two rows or banks would have two throws, and would be called a DOUBLE-THROW CRANKSHAFT (fig. 11).

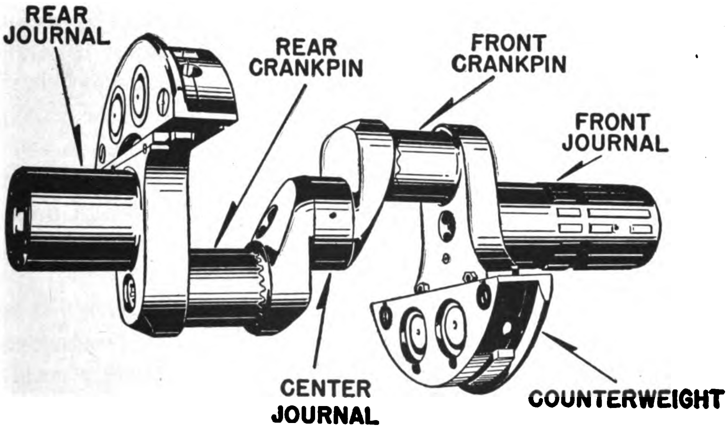


Figure 11.—A double-throw crankshaft.

Unless some means were taken to offset the weight of the throw, the crankpin, and the connecting rods, the engine would be badly out of balance and would vibrate to such extent as to prohibit proper function. Therefore, the crankshaft is equipped with COUNTER-BALANCES. These may be an integral part of the original drop forging, or they may be pieces of bronze or steel bolted to the crankshaft.

In some engines the counterbalances are arranged so that they can move slightly within reasonable limits, and are held in proper location by springs. The slight movement allowed by the springs tends to offset the force of the explosions and provide for smoother operation.

SUPERCHARGER

Modern aircraft engines are equipped with superchargers. These devices are nothing more than rotary air compressors designed to compress the fuel-air mixture delivered to the combustion chamber. This action increases the volumetric efficiency of the engine for high altitude and high r.p.m. operation.

Since the power developed by the engine is determined largely by the weight of the fuel-air mixture inducted into the combustion chamber, maximum power output for all altitudes can be greatly increased by use of the supercharger.

The supercharger (fig. 12) consists of a dynamically and statically balanced light alloy impeller rotating within an aluminum alloy housing incorporating fuel charge passages from the carburetor to the intake pipes and forming part of the engine crankcase assembly. Either a vaneless or vaned diffuser plate is used in conjunction with the impeller to convert the high velocity of the charge, caused by the high speed of the impeller, to pressure before entering the intake pipes and cylinders. The impeller is mounted on a steel shaft and driven through suitable gearing by the crankshaft.

Due to the high speed at which an impeller is driven, it is necessary to incorporate some means of relieving the stresses in the impeller drive gears when the engine is suddenly accel-

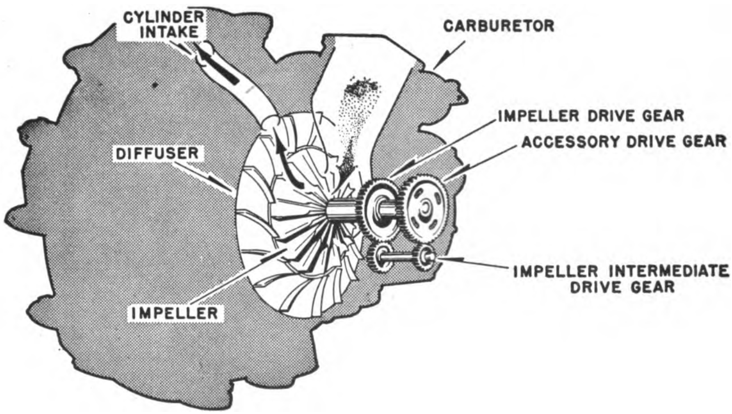


Figure 12.—Typical internal supercharger—single speed.

erated or decelerated. This is usually accomplished by a flexible coupling between the engine crankshaft and impeller gearing. This coupling, sometimes called a SPRING DRIVE, relieves gear stresses because of its cushioning effect by the transmission of the rotative force to the driven gear through springs spaced concentrically around the driving shaft.

In some engines, a coupling using engine oil under pressure for cushioning effect is employed. The oil is forced between vanes within the coupling housing which is connected to the crankshaft by means of suitable gearing which transmits the load to the drive gear of the supercharger by means of anchored weights attached to the gear.

The speed ratio at which the impeller is driven by the crankshaft varies according to the diameter of the impeller and the degree of supercharging desired.

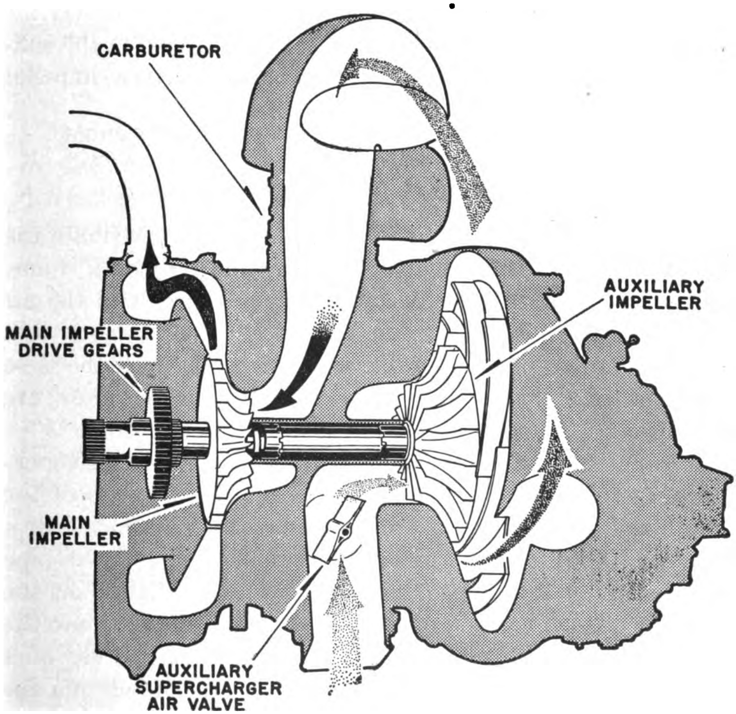


Figure 13.—Typical internal supercharger—two-stage, two-speed.

Some modern engines used for high-altitude flying are equipped to operate on either a low or high blower ratio. The pilot may change from a low setting to a high setting when an altitude is reached that requires additional supercharging to maintain comparatively high manifold pressure.

Internal superchargers are of three types: single-stage, single-speed; single-stage, two-speed; and two-stage, two-speed.

The SINGLE-STAGE, SINGLE-SPEED SUPERCHARGER consists of a centrifugal blower or impeller installed in the diffuser section. The ratio of the impeller speed relative to crankshaft speed is always the same on the single-speed supercharger. On the other hand, a SINGLE-STAGE, TWO-SPEED SUPERCHARGER has both a low-ratio drive used for take-off and lower altitudes, and a high-ratio drive for higher altitudes.

The TWO-STAGE, TWO-SPEED SUPERCHARGER (fig. 13) has the centrifugal impeller installed in the diffuser section in the conventional manner, and another similar gear-driven impeller ahead of the carburetor.

INTAKE PIPES

Intake pipes are the parts of an engine which distribute the fuel-air mixture to the various cylinders and provide a chamber for the fuel to vaporize and thoroughly mix with the air before being admitted to the cylinder. The number and design of intake pipes quite naturally depends upon the type of engine and the number of cylinders to which they are attached.

In radial engines, individual intake pipes connect the supercharger or blower section chamber to the intake ports of the cylinders. These particular intake pipes are constructed of a thin, light alloy or sheet steel. The cylinder end of the pipe is attached by a clamped hose to an integral flange on the cylinder. The lower end of the intake pipe is inserted into the ports of the blower section and made gas-tight by use of a rubber ring and locking nut. This arrangement permits the intake pipe to move with the elongation and contraction of the cylinder, thus preventing distortion.

EXHAUST MANIFOLD

The purpose of the exhaust manifold is to conduct the burned gases from the engine to the slipstream.

Three general types of exhaust systems have been designed. Early engineers used the short stack type which was abandoned because of the fire hazard, its interference with the pilot's vision, and its visibility at night, the latter reason due to flames emitting from the stack. The next type of exhaust system utilized a short stack which was flattened along a beveled edge in an attempt to correct the above-mentioned faults. This was known as the bayonet type.

The most common type of exhaust system in current use is the COLLECTOR RING or MANIFOLD type. In this design, the individual stacks are connected to a ring or manifold by means of a slip joint which permits expansion of the system.

ENGINE SECTIONS

Engine sections, as illustrated in figure 14, serve as housings for the integral parts of the crankshaft, reduction gears, and drive assemblies of the engine. They afford rigidity to the entire engine structure and serve as the base or bed member on which the engine is built.

Engine sections support the cylinders and crankshaft and serve as the means of attaching the engine to the fuselage. You will discover, as you work on engines, that engine sections in general provide rigidity, tie various parts of the engine together, and withstand stresses created by gas pressures. They also provide a tight enclosure to prevent the loss of lubricating oil and to protect internal engine parts from dust and dirt.

The POWER SECTION of a typical twin-row radial engine is composed of three forged steel or aluminum alloy sections—front, center, and rear—held together by through-bolts. Around the outer circumference of the power section assembly, cylinder mounting pads are arranged. A chamber called a SUMP is provided on the lower side of this section to collect the oil supply.

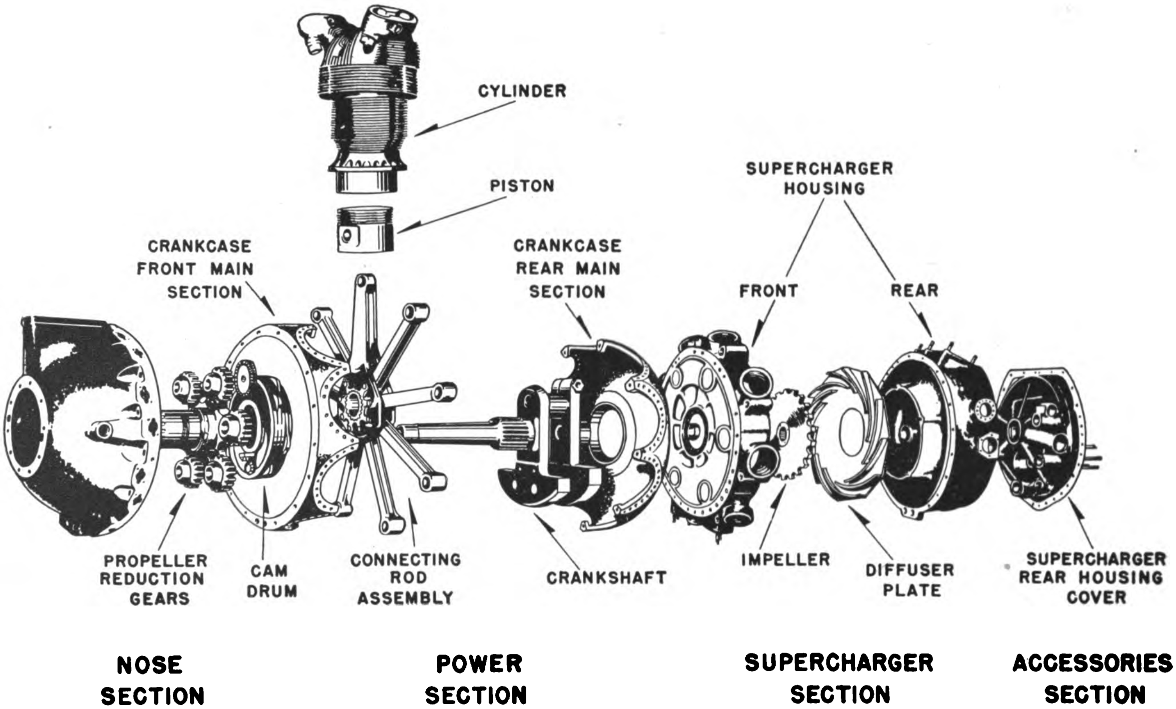


Figure 14.—Engine sections.

The supercharger is located at the rear of the power section and housed in the SUPERCHARGER SECTION.

The accessory drives in the ACCESSORIES SECTION lead to mountings where the necessary accessories may be attached.

Just forward of the power section is the NOSE or FRONT SECTION, which acts as a housing for the reduction gears and propeller shaft assembly.

REDUCTION GEARS

In early airplanes, the propeller was usually of the direct drive type (fastened directly to the crankshaft) because engine speeds in those days were relatively low. As experience was gained and the technique of vibration survey developed, crankshaft speeds progressively increased. At the present time, a speed of 2,600 r.p.m. for a large engine is not considered

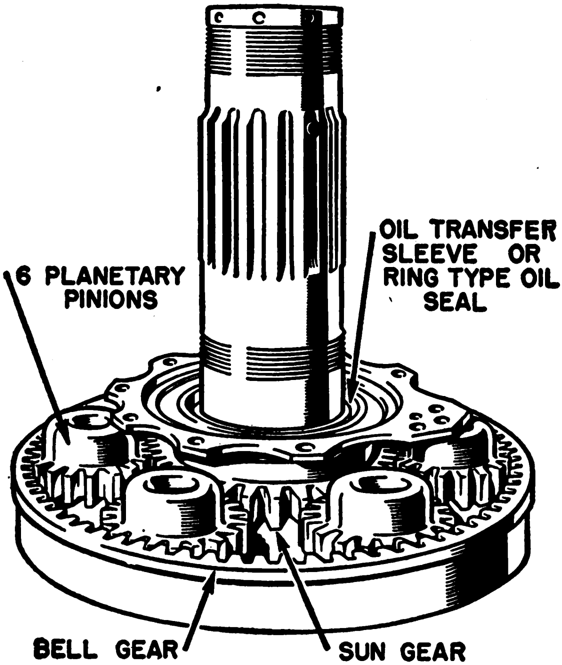


Figure 15.—Propeller reduction gear.

excessive. You will find a few of the lower powered engines which rotate as high as 3,000 r.p.m.

Increasing crankshaft speeds made it necessary to provide a propeller reduction gear in order to limit the tip speeds of long propeller blades. Your study of propellers will teach you this. For the present, however, it is important that you realize the desirability of limiting tip speeds in order to keep the tips out of a vibration range which might cause failure.

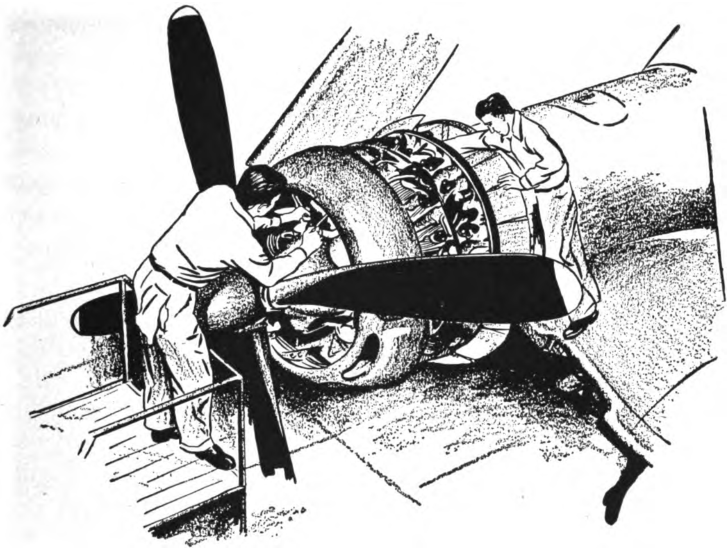
You will learn that various types of propeller reduction gears are used. The PLANETARY type, illustrated in figure 15, is that which you will most often encounter. Briefly, this type operates as follows.

A bell-shaped gear with teeth on its inside edge (and attached to the crankshaft) drives several planetary pinions (small gear wheels). These in turn move around the rim of a stationary sun gear. Rotation of the planetary pinions drives the propeller shaft and spider assembly.

Because of the gear arrangement, the propeller shaft rotates at a lower speed than the crankshaft. A variation in gear ratios is obtained by using a stationary bell gear and a driving sun gear. You will find that there are various gear ratios in use, depending upon the make and model of the aircraft engine.

QUIZ

1. Name the three most common types of poppet valves.
2. Are heat-resistant qualities more important in the intake valve or in the exhaust valve?
3. What are the two functions of piston rings?
4. On what major assembly are the counterbalances located?
5. What is the most frequently encountered propeller reduction gear assembly?
6. Name the three types of gears used in the above assembly.
7. Of what material are aircraft pistons usually made?
8. What type of piston pin is used in aircraft pistons?
9. What is the part that links the piston and the crankshaft?
10. What is the function of a supercharger?



CHAPTER 3

IGNITION SYSTEMS

When a mixture of fuel and air is admitted into a cylinder and compressed, the next step in the cycle of operation is the ignition of the compressed charge at the proper time.

IGNITION is the firing of the explosive mixture of gases in the cylinders of reciprocating engines. This effect is efficiently and conveniently obtained by means of an electric spark which is produced when electricity is forced to jump across the gap between the electrodes of a spark plug installed in the combustion chamber.

An electrical ignition system furnishes these sparks periodically to each cylinder at a predetermined position of piston travel. The source of high-voltage sparks may be either a MAGNETO driven by the engine or an INDUCTION COIL energized by a battery or generator.

MAGNETOS

The magneto, which is the usual source of high-voltage electricity in modern aircraft engines, is simply a self-contained

generator and transformer. It operates on the principle of electromagnetic induction.

ELECTROMAGNETIC INDUCTION is produced in two ways:

1. By relative motion between a conductor and a magnetic field so the conductor "cuts the flux."
2. By changing the concentration of the magnetic field linked with a conductor (changing flux intensity through an iron core of a coil, such as a transformer).

Both methods are employed in magnetos.

Figure 16 shows how the concentration of flux in a magneto is varied. A four-pole permanent magnet rotates between the pole shoes of an unmagnetized soft-iron yoke or core. The pole shoes are spaced so that they are simultaneously adjacent to two magnetically opposite poles of the rotating magnet.

As you can see, the position of the rotating magnet poles with respect to the pole shoes determines the direction and concentration of flux in the core.

In figure 17, a complete schematic diagram of the magneto is shown. Approximately 150 turns of comparatively heavy wire are wound around the core to form a primary coil, and a secondary coil is formed by winding several thousand turns of fine wire around the core.

One end of the primary coil is permanently grounded. The other end is connected to ground through a pair of contact or "breaker" points normally held together by spring tension. The primary circuit is therefore complete when the breaker points are closed. A primary condenser is connected in parallel across the points.

One end of the secondary coil is grounded with the permanent ground connection of the primary coil. The other end of the secondary reaches the spark plugs through the distributor rotor, distributor block, and spark plug wiring.

Electrically and mechanically, the circuits within the magneto are so closely linked with one another that any action in one circuit is reflected by induction in the other. When the poles of the magnet are in position (A) of figure 16, the concentration of the magnetic lines of force through the core reaches its maximum.

As the magnet continues to rotate, the concentration of mag-

netic flux diminishes to zero at the neutral position, (B) of figure 16. Continuing to rotate, the magnet again builds up the flux concentration to a maximum (C), and again diminishes it to zero. This change in magnetic flux concentration produces a change in the flux linkages through the primary coil, thereby inducing a current in the primary circuit.

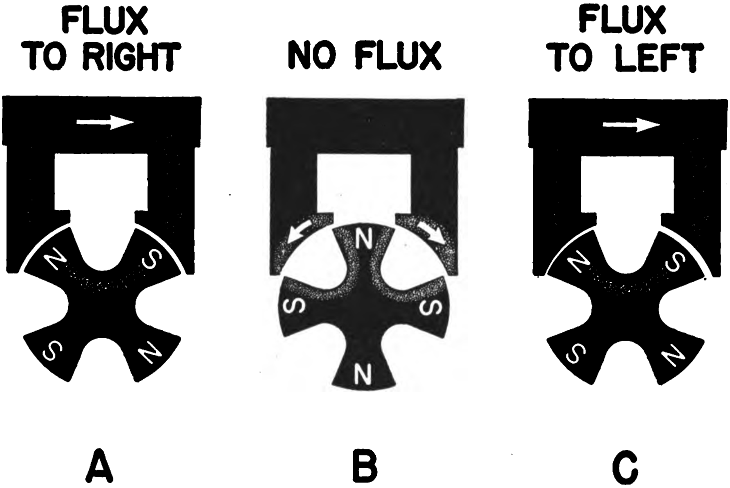


Figure 16.—Magnetic flux concentration at three positions of the magnet.

The breaker points are periodically opened and closed by a cam located at one end of the magnet drive shaft. The points are adjusted to open or break the primary circuit when the induced current in the primary coil has reached its maximum.

When the primary circuit is broken, the magnetic field around the primary windings collapses almost instantly, and the secondary windings cut the magnetic lines of force at a rapid rate. This action induces a high-tension current in the secondary coil which is discharged through the distributor rotor, distributor block, spark plug wiring, and across the spark plug gap to ignite the fuel-air mixture in the combustion chamber.

CIRCUITS

Operating principles of a magneto are based upon the rela-

tionship of its three circuits, which include the magnetic, primary, and secondary circuits.

The MAGNETIC CIRCUIT consists of a permanent magnet or magnets, the core, and pole shoes. The permanent magnets provide the magnetic field or lines of magnetic force which are necessary for the production of electric current by induction.

The core concentrates the lines of force flowing from the poles of the magnet, and makes them link the turns of the primary coil.

The PRIMARY CIRCUIT consists of a primary coil, an automatic switch, a manual-control switch, and a primary condenser, as illustrated in figure 17.

The primary coil is constructed of comparatively few (150 to 300) turns of enameled copper wire wound directly around the core. One end of the primary coil is grounded to the soft iron core, the other connected to the insulated contact or breaker point.

The breaker points act as an automatic switch, and are

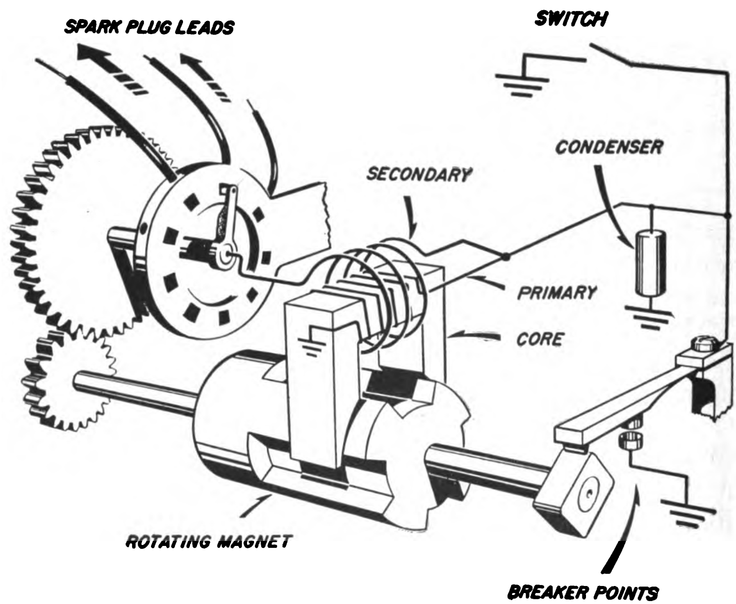


Figure 17.—Schematic diagram of a magneto.

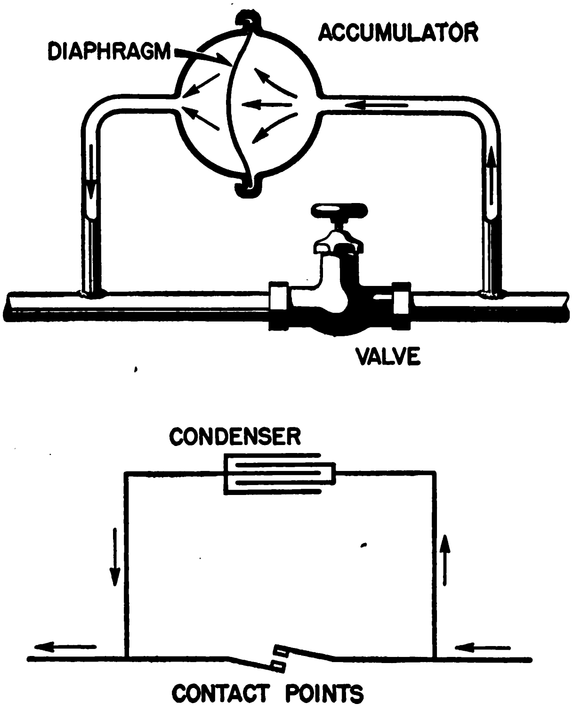


Figure 18.—Condenser action.

operated by a cam located either on one end of the magnet drive shaft or independently driven.

When the breaker points open, the magnetic field created by the primary current collapses. This action results in a self-induced current that attempts to flow or surge across the points for a short period of time. This surge, unless checked, would create an electric arc across the points which, in turn, would burn the points and eventually cause the magneto to fail.

To eliminate arcing and burning, a condenser (capacitor) is placed in parallel with the breaker points. The action of the condenser is comparable to that of the air bell shown in the water analogy diagram of figure 18. The air bell prevents "banging" of the valve by absorbing the shock caused by inertia of the water when the water is suddenly shut off. Simi-

larly, the condenser prevents arcing across the breaker points when they open, by absorbing the "inertia" of the self-induced current in the primary coil.

The manually-controlled magneto switch or induction switch provides a means of turning the magneto on and off as desired.

The ignition switch terminal or magneto ground terminal on the magneto is connected electrically to the insulated breaker point, as demonstrated in figure 17. Wires connect the ground terminal on each magneto to the ignition switch. With the switch at "off" position, these wires provide a direct path to ground. Therefore, when the circuit breaker points open, the primary circuit is grounded, preventing generation of high voltage in the secondary circuit.

The SECONDARY CIRCUIT consists of a secondary coil, distributor finger (rotor), distributor block, high-tension cables, and spark plugs.

The secondary coil is constructed of a large number of turns of enameled copper wire wound around or atop the primary coil and covered with a hard rubber or bakelite case. One end of the secondary winding is generally grounded with the primary ground. The other end is connected to the distributor finger, or in some cases to a secondary condenser located in the rotor.

The secondary condenser stops the afterflow of current in the secondary coil and assists in generation of current in the primary coil.

As the distributor rotor revolves, it delivers high-tension current from the secondary coil to each successive distributor block electrode. It operates as an automatic switchboard.

For each cylinder on the engine, the distributor block provides one electrode or terminal to which the high-tension spark plug cables are attached in proper sequence. The numbers on the distributor block denote the magneto firing order—not the firing order of the engine. The distributor block terminal marked #1 must be connected to the #1 cylinder; terminal #2 to the next cylinder to fire; terminal #3 to the next cylinder to fire, and so on.

As stated previously, current is induced in the primary coil windings when the magnets are moving from the full flux posi-

Figure 19.—"E" gap position.

tion toward the neutral position. When the current in the primary coil has reached its peak, the breaker points are opened by a cam, causing the magnetic field created by the current flowing in the primary coil to collapse.

As this occurs, the rapidly collapsing lines of force are cut by the windings of the secondary coil. Approximately 20,000 to 25,000 volts are thereby induced in the secondary coil. This is sufficient to cause an arc to jump the spark plug gap and ignite the fuel-air mixture in the combustion chamber.

The breaker points are adjusted or internally timed to open at the "E" gap position, which is THE NUMBER OF DEGREES BETWEEN THE NEUTRAL POSITION OF THE ROTATING MAGNET AND THE POSITION WHERE THE BREAKER POINTS OPEN (fig. 19). Since the "E" gap varies in different magnetos, it should not be set without reference to the manufacturer's specifications.

Except in the case of a compensated cam, the cam has as many lobes as there are poles on the magnets. The number of

sparks produced in one revolution of the magnet shaft is equal to the number of poles on the magnets.

BREAKER ASSEMBLIES

There are three types of breaker assemblies now installed on aircraft magnetos—the Scintilla Pivot, Scintilla Pivotless, and the American Bosch Pivotless.

The PIVOT type (not used on recent models) derives its name from the pivot shaft on which the moving breaker arm is mounted.

The PIVOTLESS breaker assembly (fig. 20) is named for the method of mounting the movable breaker point arm lever. This lever is supported by a steel spring which permits movement without wear. Pivotless points are adjusted to open in accordance with "E" gap specifications. Point clearance is disregarded, since that function has been provided for in the design of the magneto.

Each breaker assembly requires a different method of adjustment.

COMPENSATED-TYPE BREAKER CAMS

The magnetos of some high-powered radial engines are equipped with compensated-type cams. The cam lobes are spaced at unequal intervals to compensate for the top-dead-center variations of each piston caused by the elliptical travel of the knuckle pins on the articulating rods.

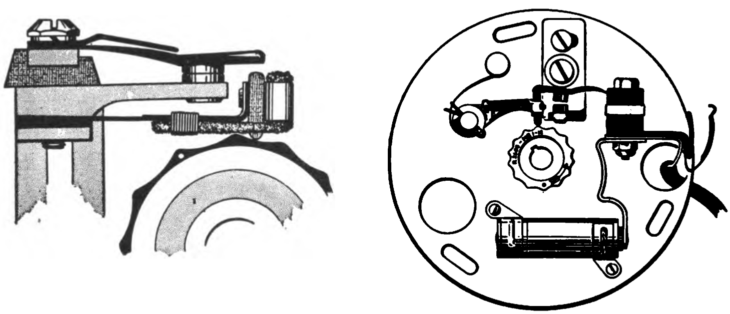


Figure 20.—Pivotless-type breaker assemblies.

When timing the compensated-type magneto to the engine, the lobe marked with the zero, or red dot, must be used in setting the breaker points. The magneto must be timed to the proper cylinder so that the unevenly spaced lobes will be in proper relation to the cylinders they fire.

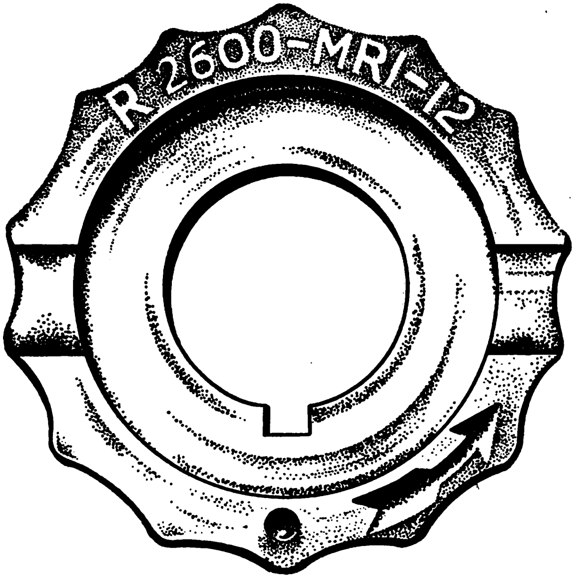


Figure 21.—Compensated cam for 14-cylinder engine.

Compensated cams (see fig. 21) are etched with the location of the master rod or rods, and the "E" gap setting in degrees. They are not interchangeable. For example, a compensated cam marked with master rod locations of 8 and 13 cannot be used in an engine in which the master rods are located in No. 1 and No. 10 cylinders.

STAGGERED AND SYNCHRONIZED TIMING

The peculiarities of combustion chamber design and spark plug location sometimes necessitate the use of STAGGERED TIMING. In such cases, the spark plug nearest the exhaust valve is set to fire at from 4 to 8 degrees of crankshaft travel

before the spark plug on the intake side. The mixture near the exhaust valve does not fire as rapidly as the fresher mixture near the intake valve.

SYNCHRONIZED TIMING means that both engine magnetos are set to permit the spark plugs in a cylinder to fire simultaneously.

IGNITION SWITCHES

Control of the ignition units, separately and in all necessary combinations, is provided at one point in the cockpit by the ignition switch. The control switch for a magneto is connected in parallel with the breaker points. In the "off" position, the switch is CLOSED, thereby short-circuiting the breaker points. Thus, the magneto is inoperative because no interruptions of primary current occur even though the breaker points are successively opened and closed.

When the control switch is in the "on" position, the switch is OPEN, and the magneto is then operative because the primary current is interrupted by the action of the breaker points.

A switch used in connection with a single-engine magneto ignition system has three "on" positions, marked "L" (left), "R" (right), and "both." Battery voltage must pass through the ignition switch, and until the switch arm is placed in the "both" position, battery voltage is not supplied to the booster or starter solenoid switches. Thus, the ignition switch acts as a safety device. When the switch is in any position other than the "both" position, thoughtless closing of either the booster or starter switch can do no harm.

The twin-engine magneto ignition switch provides independent control of each magneto on each engine. In addition, it includes an emergency safety switch which, in the "off" position, grounds all magneto primaries and opens the battery circuit leading to the booster and starter switches. The switch must be placed in the "on" position before the engines can be started.

INDUCTION VIBRATOR

When slow starting speeds make it impossible to rotate engine-driven magnetos fast enough to produce the spark

necessary to ignite the fuel-air mixture, a source of external high-tension current is needed. This requirement may be provided by an induction vibrator.

When the ignition switch is in the "on" position, and the starter is engaged, the current from the battery is sent through the coil of the relay, causing the relay points to close. This completes the circuit to the vibrator coil, and the vibrator transmits a rapidly interrupted current.

This current is sent through the primary winding of the magneto coil where, by induction, a high voltage is created in the secondary winding of the magneto coil. This produces high-tension impulses which are delivered to the spark plugs through the magneto distributor rotor and distributor block electrodes when the magneto contact points are open.

The initial impulses, or sparks, are timed in advance, but the sparks which follow gradually taper off into retard until the magneto points close and the current is bypassed to ground. This action is repeated each time the magneto contact points are separated, sending the interrupted current again through the primary of the magneto coil where the action, as outlined above, again takes place.

This action continues until the engine is firing by means of the regular magneto spark and the engaged starter is released.

No special operating instructions are needed, as the vibrator automatically starts functioning when the switch is in the "on" position and the starter is engaged, and ceases to function when the starter is disengaged.

MAGNETO TYPES AND MODELS

The various types and models of standard aircraft magnetos are designated by a code symbol of letters and numerals which may be broken down as follows:

Thus, a magneto marked with the code DF 18 RN 14 would indicate that it was a double magneto, flange-mounted, for 18 cylinders, right rotating, manufactured by Scintilla, and model or modification 14.

Most modern aircraft engines use two single magnetos or one double magneto mounted either on the accessory or the nose

S F 14 L U 10

- 10 — Model or identification number.
- U — Manufacturers' code: U— American Bosch, N— Scintilla, and D— Edison-Splitdorf
- L — Direction of Rotation: L— Left and R— Right.
- 14 — Number of cylinders
- F — Mounting: F— Flange and B— Base.
- S — Construction: S— Single and D— Double.

section of the engine. However, the Pratt & Whitney R–4360 engine uses seven double magnetos, each magneto providing ignition for four cylinders.

The double magneto may be considered as two magnetos in one, since it contains two sets of coils, two sets of breaker points, and two sets of primary and secondary condensers. However, it uses only one inductor, or rotor magnet, to energize both sets of coils.

The distinguishing feature of the double magneto is the use of two independently mounted distributor blocks connected to the magneto unit by independent high-tension feed wires.

LOW–TENSION IGNITION SYSTEMS

The low-tension ignition system is designed to reduce the tendency of "flashover" or "shorting" of high-tension current because of low atmospheric pressure at high altitudes, or moisture from condensation. The location of high-tension induction coils near each spark plug reduces electrical loss usually found in long high-tension cables.

The electrical operation of the low-tension, high-altitude system differs from the high-tension system primarily in that an IGNITION GENERATOR produces only primary current (fig. 22). This primary current is transmitted through the primary leads to the separate low-tension distributor and breaker units. From low-tension distributors, the current is delivered

through a low-tension harness to individual high-tension induction coils for each spark plug.

The ignition generator consists of two four-pole rotating magnets, four primary coils, a junction box for making the primary connection from the primary coils to the distributor units, the ground switch, and primary booster.

Two four-pole magnets are mounted on the same shaft between two annular ball bearings with the poles of one magnet staggered 45 degrees in relation with the other. When the magnet rotates, a primary current is alternately built up every 45 degrees in the two coils on one side of the generator, giving eight consecutive current impulses per revolution.

Since the generator is driven at $1\frac{1}{8}$ engine speed, 9 dual primary build-ups occur for each engine revolution. This fulfills the ignition requirements for an 18-cylinder, 4-stroke cycle engine.

The low-tension coils in the generator have only primary

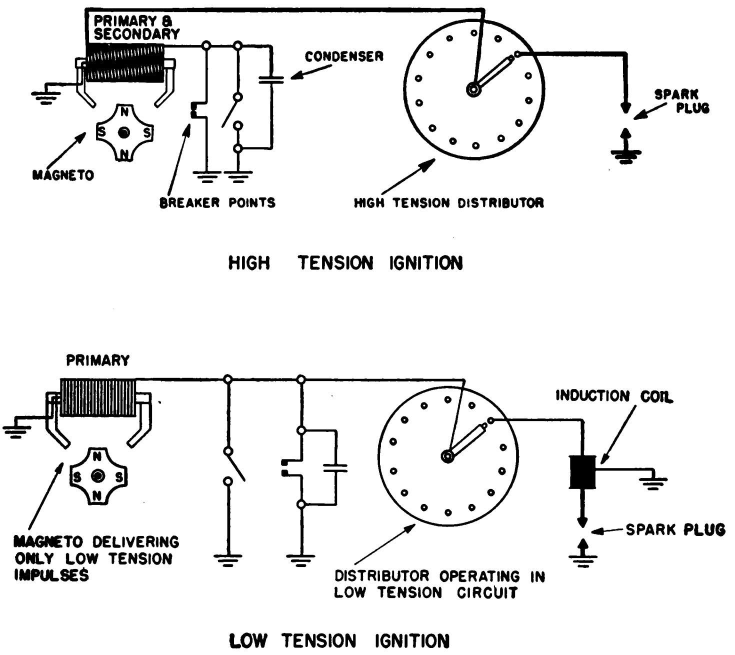


Figure 22.—High- and low-tension ignition systems.

windings, and are cast integrally with the generator housing. The #1 coils on the right and left sides of the generator are connected to the insulated sides of the #1 breaker assemblies in the right and left distributors, to the primary condensers, and to the #1 collector rings of the distributor units.

In like manner, the #2 coils on the right and left sides of the generator are connected to the #2 breaker assemblies in the right and left distributors, to the primary condensers, and to the #2 collector rings of the distributor units.

The two distributor units are identical, and have standard three-bolt flanges with elongated holes for timing the engine. A hydraulic advance mechanism, providing 10° spark advance, is incorporated in drive and mounting flange. This is normally in full retard position, and advances on application of oil pressure from the engine torquemeter.

Two nine-lobe compensated cams, keyed to the drive shaft, operate the breaker points.

A distributor finger on the end of the shaft makes contact between the collector rings and segments of the distributor head through carbon brushes. The distributor head is an integral part of the harness and forms the rear cover for the distributor unit. This head is attached to short, flexible conduits which carry 18 primary wires from each distributor to the ring manifold of the harness and two primary feed wires from the generator.

The booster wires also pass through one of these conduits to the right-hand distributor.

The ring manifold carries 36 primary wires from the distributors, the feed wires from the generator, and the booster wire.

Nine flexible conduits, attached to the manifold and terminated by four terminal plug-in connectors, complete the primary connections to the high-tension induction coils.

The high-tension induction coils for each spark plug are grouped, two in each coil assembly, and are mounted on the cylinder heads. Each assembly serves the front and rear spark plugs of one cylinder.

Short, shielded high-tension leads carry high-tension current from the induction coils to the spark plugs.

A special low-tension battery booster is connected to the low-tension distributor through separate breaker points so arranged that booster current passes to the high-tension coil circuit only when the main breakers open and the booster breakers close. This condition is governed by the breaker cam arrangement and occurs at such intervals as to insure properly retarded spark.

When the flow of primary current in the generator coils is interrupted by the opening of the main breaker contact points, the surge of current is directed by the low-tension distributor through the low-tension harness to the primary winding of the proper high-tension induction coil. A high-tension current is induced in the secondary winding of the coil, causing the spark to occur at the spark plug.

IGNITION HARNESS

An ignition harness (fig. 23) is an assembly of electric cables and terminals enclosed in a manifold for use in the ignition system of an engine.

There are two general types of ignition harnesses—the conventional tubular type, and the newer cast-filled harness.

The CAST-FILLED harness is especially designed and constructed to eliminate the troublesome features of the tubular harness. The cast-filled manifold and distributor housings are filled with a dielectric sealing compound creating a sealed unit which, when properly maintained, eliminates the common faults of ignition wiring.

The conventional TUBULAR manifold is made of aluminum or stainless steel tubing. For radial engines, the manifolds are usually in the form of a hoop or two halves of a circle. The cables are thus protected from the heat of the engine, from abrasion caused by vibration, and from deterioration caused by oil and grease.

Both high-tension and low-tension wiring are used. The high-tension cables are made of many small stainless steel wires twisted together and heavily insulated with cord and rubber. They are used in the high-tension circuits, such as that from the booster to the distributor and that from the dis-

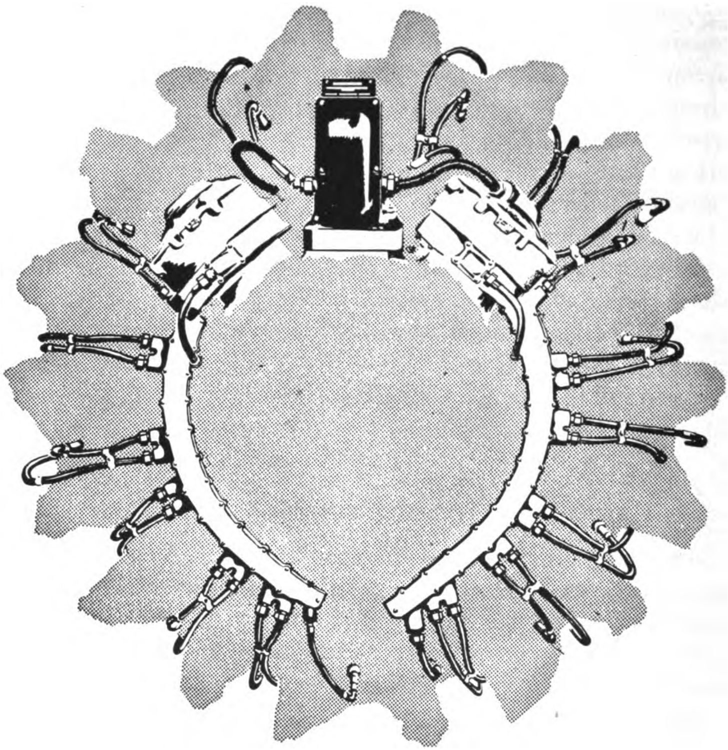


Figure 23.—Ignition harness.

tributor to the spark plugs. The low-tension cable is composed of fewer twisted copper wires, lighter in weight and less heavily insulated. Low-tension cable is used in the ground circuits. High- and low-tension wires are never included in the same conduit.

An electromagnetic field surrounds an ignition cable each time a discharge of current passes through it. If the cables were merely rubber-covered, this disturbance would ordinarily be picked up by the radio receiving set, thus creating interference. In order to prevent such interference, all ignition cable is enclosed in metal housings or manifolds, and all exposed portions are covered with braided metal casings.

In fact, on aircraft equipped with radio, the entire ignition

system is shielded to insure adequate reception of signals. All such shielding must be firmly grounded so that the electrical energy absorbed may be properly dissipated. Magnetos and spark plugs are also thoroughly shielded to prevent radio interference.

SPARK PLUGS

One of the most vital parts of the ignition system, the spark plug must operate under high pressures and high temperatures.

The average operating temperature of the insulator and the intensity of the flame across the electrodes must be sufficient to prevent fouling when the engine is operating at low power output, under extremely cold atmospheric conditions, or when throttled down during long descents. If the operating temperature of the spark plug is too high, the end of the insulator and the electrodes located within the combustion chamber may become white-hot or incandescent, causing preignition.

Oil, carbon, or lead deposits (from gasoline) on a fouled plug will short-circuit the electrodes and cause firing failure.

The precision with which spark plugs are built requires that they be handled as delicate instruments. This point cannot be emphasized too strongly. Spark plugs should never be carelessly thrown around, but rather should be placed—not dropped—in work trays.

There are two types of spark plugs in use—those with CERAMIC insulators, and those which are MICA-INSULATED.

The two principal units of the ordinary mica spark plug are the CORE and the SHELL, as shown in figure 24. The core includes a center electrode (spindle) made of steel and copper. The steel is used for strength, while the copper carries away the heat.

Surrounding the electrode is a mica "cigarette" enclosed with mica washers which form part of the core nose. These washers are held securely in place by a brass core wedged into the body of the plug.

The steel shell may or may not be finned. It has its own set of ground electrodes, and is assembled to the core by internal threads. The shell is externally threaded for installa-

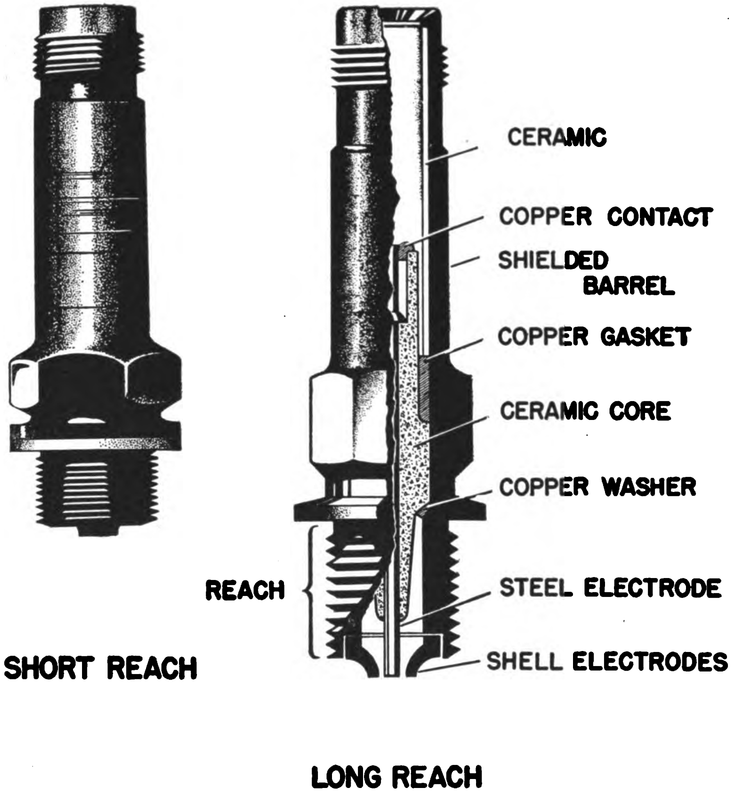


Figure 24.—Shielded aircraft spark plugs.

tion in the cylinder head. Suitable gaskets are provided to prevent leakage between the spark plug and cylinder head.

Spark plugs may be classified according to REACH—the length of thread engagement into the cylinder head. For example, "short reach" indicates comparatively short threads, while "long reach" means long threads.

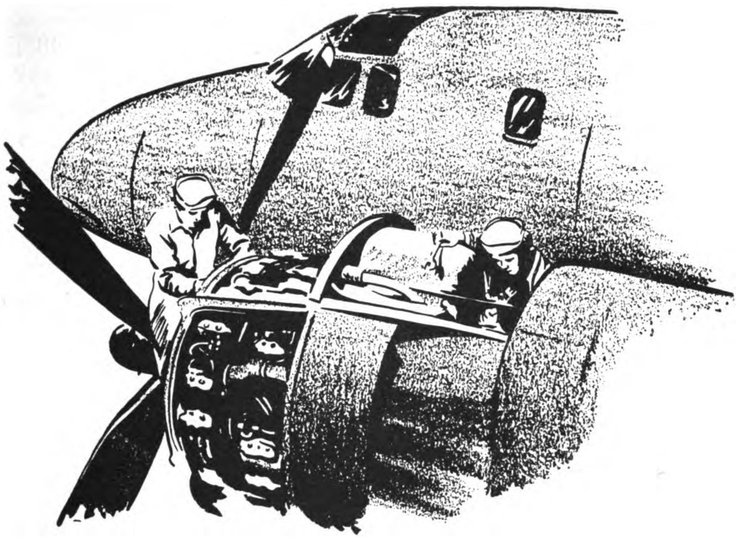
Another common classification of spark plugs is by heat range. Although there are several factors influencing the operating temperature of a spark plug, a fundamental factor concerns the amount or length of spark plug core exposed to the heat of combustion. The distance heat must travel from

the tip of the core to the cylinder head determines operating temperature of the plug.

Spark plugs having a long core will run hotter than those with a comparatively short core. HOT PLUGS have long cores, while COLD PLUGS have short cores. The cold plug is used on engines having high operating temperatures, and the hot plug on engines with low operating temperatures.

QUIZ

1. How is arcing and burning across the breaker points in the primary circuit eliminated?
2. Select the proper units to complete the primary ignition circuit and those to complete the secondary ignition circuit:
   a. Spark plugs.
   b. Breaker points.
   c. High-tension cable.
   d. Distributor rotor.
   e. Control switch.
   f. Coil with 150 windings.
   g. Distributor block electrodes.
   h. Primary condenser.
   i. Coil with 1500 windings.
3. Why is the opening of the breaker points in the primary circuit an essential element in the production of high-tension current at the spark plug?
4. What is the purpose of a compensated-type breaker cam?
5. What is synchronized timing?
6. What is the purpose of an induction vibrator?
7. What engine fault is likely to occur when spark plug operating temperature becomes too high?
8. Generally speaking, which spark plug will run the hotter—one with a long core, or one with a short core?
9. Identify this hypothetical magneto model: DB18LD2.



CHAPTER 4

ENGINE ACCESSORIES

The majority of aircraft engine accessories are presented in other volumes of the Aviation Series of Navy Training Courses. For example, propellers and propeller controls are covered in *Aircraft Propellers*, NavPers 10336; carburetors, fuel pumps, and fuel-line accessories are described in *Aircraft Fuel Systems*, NavPers 10335; and engine instruments are covered in *Aircraft Instruments*, NavPers 10333.

Magnetos, distributors, condensers, booster coils, spark plugs, and ignition wiring were presented in the chapter just discussed. There are, however, certain engine accessories not presented elsewhere in this series of Navy Training Courses. Among these are starters and generators, which you will now consider.

AIRCRAFT ENGINE STARTERS

An internal combustion engine, to start, must be cranked at a relatively high speed through at least the intake and com-

pression strokes, and past the firing point of at least one cylinder. The mechanical device used to crank an engine is known as a STARTER. However, the starter is not the only unit necessary for starting. Ignition and carburetion must also be called upon before the engine will start.

Inertia starters are in general use in the Navy today. Prior to World War II, many naval aircraft used cartridge-type starters.

Various types of starter accessory units—such as solenoid meshing devices, solenoid starting switches, battery booster coils, control switches, and external energizers—are used in conjunction with starters to facilitate installation and improve operation.

INERTIA STARTERS

Inertia is that property of matter which causes a body at rest to tend to stay at rest and a body in motion to continue in motion unless acted upon by some external force. All inertia starters operate on the principle that energy in cranking is stored as momentum in a spinning flywheel. There are three types of inertia starters—the HAND INERTIA, the ELECTRIC INERTIA, and the ELECTRIC INERTIA WITH DIRECT CRANKING.

HAND-OPERATED INERTIA STARTERS

Widely used and very efficient, the hand inertia starter cranks the flywheel until it is rotating at high speed, then engages the flywheel with the engine starter jaw through a train of gears and a multiple-disc clutch.

The crank is coupled to the flywheel through a set of planetary-type gears with a ratio of approximately 150 to 1. At a cranking speed of about 80 r.p.m., the average speed of the small, heavy flywheel will be approximately 12,000 r.p.m. Thus, the momentum of the spinning flywheel will crank the engine through several revolutions.

A spring-loaded multiple-disc clutch prevents injury to the starter mechanism caused by backfiring or excessive torque. The torque of the starter is transmitted by the clutch through a helically splined engaging mechanism and through the starter

jaws to the engine. The engaging mechanism may be operated externally or from the cockpit.

The control may be manually operated by means of a push-pull system, or by an electrically operated solenoid which advances the starter jaws into engagement with the engine jaws. When the engine starts, rotation of the engine jaws is so much faster than rotation of the starter jaws that the jaws automatically disengage.

Some types of hand inertia starters are equipped with an integral booster magneto geared to the flywheel through a friction clutch. The booster magnetos will supply a hot starting spark until the engine-driven magnetos reach their coming-in speed. Other types will be equipped with some form of booster coil which serves the same purpose.

ELECTRIC INERTIA STARTERS

The electric inertia starter is basically similar to the hand inertia starter. The difference lies in the flywheel housing cover assembly which incorporates an electric accelerating motor instead of the usual hand crank to energize the flywheel. However, electric inertia starters are generally equipped with a provision for hand cranking in an emergency.

An electric inertia starter equipped with a solenoid starting switch and a solenoid meshing or engaging device is usually controlled by means of a double-throw toggle switch located in the cockpit.

ELECTRIC INERTIA STARTER WITH DIRECT CRANKING

The chief difference between the electric inertia starter with direct cranking (fig. 25) and the electric inertia starter just discussed, is that in the former the starting motor and flywheel are combined as one unit. The electric motor in this type of starter continues to drive the engine after the flywheel has overcome the initial inertia of the engine.

In operation, the flywheel is energized before the starter is engaged. After engagement of the starter, the starter motor continues to drive the engine until it "catches." The installation requires a special wiring circuit and a special switch.

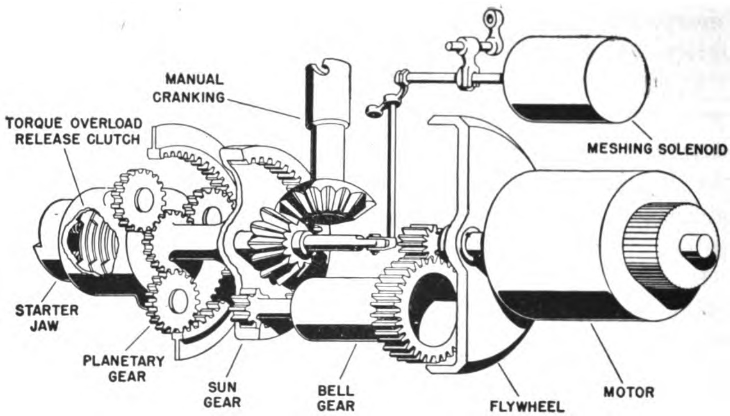


Figure 25.—Combination electric inertia and direct cranking starter.

DIRECT ELECTRIC STARTERS

The direct electric starter, which is widely used on late model naval aircraft, is made up of a heavy-duty electric motor with the necessary reduction gearing, overload clutch, and automatic engaging device. Its chief advantages are that it provides instant cranking, and that it eliminates the heavy weight of the flywheel necessary in the electric inertia types.

The direct electric starter requires considerably more power for continuous operation than any other starter.

CARTRIDGE STARTERS

The cartridge (combustion) starter, which derives its energy from the expansion of burning gases, is a practically obsolete type of starter. It has sometimes been called a "shotgun" starter. This device consists of a cylinder and piston, intake and exhaust tubes, breech mechanism, and electrical firing switch.

The cartridge starter produces a high cranking speed for a short period of time, but is not as reliable as other types. Its operation is comparatively expensive, and it requires considerable maintenance attention. Because of these disadvantages, the cartridge-type starter has practically disappeared from naval aircraft.

AIRCRAFT GENERATORS

A GENERATOR IS A DEVICE WHICH CONVERTS MECHANICAL ENERGY INTO ELECTRICAL ENERGY. Electrical power required for the operation of the various electrically operated aircraft units is supplied by a generator mounted on the rear (accessory) section of the engine. When the demand for electrical power exceeds the output of the engine-driven generator, an auxiliary electrical power plant may be installed to supply the additional requirements of the multitude of units found on large aircraft.

Since the maintenance of an aircraft generator is generally considered to be one of the duties of Aviation Electrician's Mates, no attempt will be made here to describe the minute details of operation. However, it is highly desirable that you, as an Aviation Machinist's Mate, have sufficient knowledge of the types and operating principles of aircraft generators to enable you to carry on in cases of emergency.

GENERATOR TYPES

The type of generator used on any particular plane depends upon the amount of power required and the nature of current needed to operate the individual units. Radio communication equipment generally requires alternating current for its operation. Other units require direct current. Therefore, generators may be constructed to supply either alternating current or direct current, or both.

The engine-driven generator is usually a direct-current device, since one of the prime requirements of a generator is the furnishing of a source of direct current for charging the aircraft battery. It is impossible to charge a storage battery with alternating current without first converting (rectifying) the alternating current into direct current, and this necessitates the use of additional heavy equipment. Some generators are equipped with two sets of windings, designed to supply both alternating and direct current. This type of generator is shown in figure 26.

When the generator is idle, a small amount of residual magnetism remains in the iron core or pole shoes. This residual

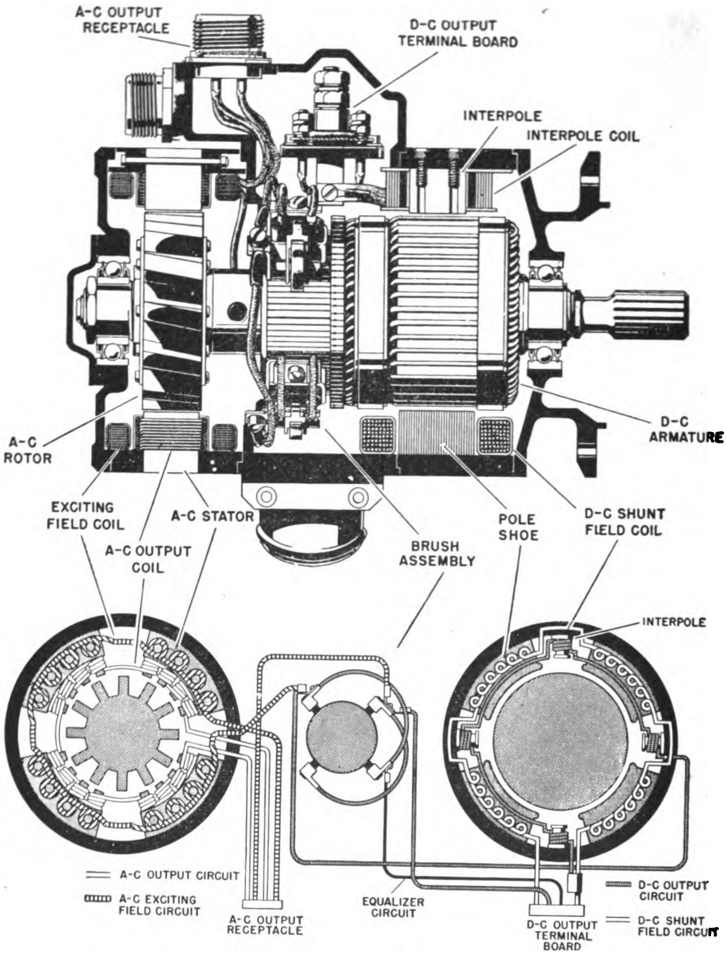


Figure 26.—AC-DC generator.

magnetism furnishes the initial flux required for the generator to produce the initial current. Initial current rapidly builds up the magnetic field as the generator gains speed.

Since it is imperative that the weight of a generator be kept to a minimum, it becomes necessary to increase the output of the generator without a corresponding increase in weight. This has been accomplished by stepping up armature speeds until they approach the maximum safe limits.

One factor which has limited the power output of a generator has been the production of destructive heat as a byproduct. Cotton, silk, or enamel insulation used on generator wiring will break down under extreme heat, making it necessary to keep generator temperature below the critical heat limit.

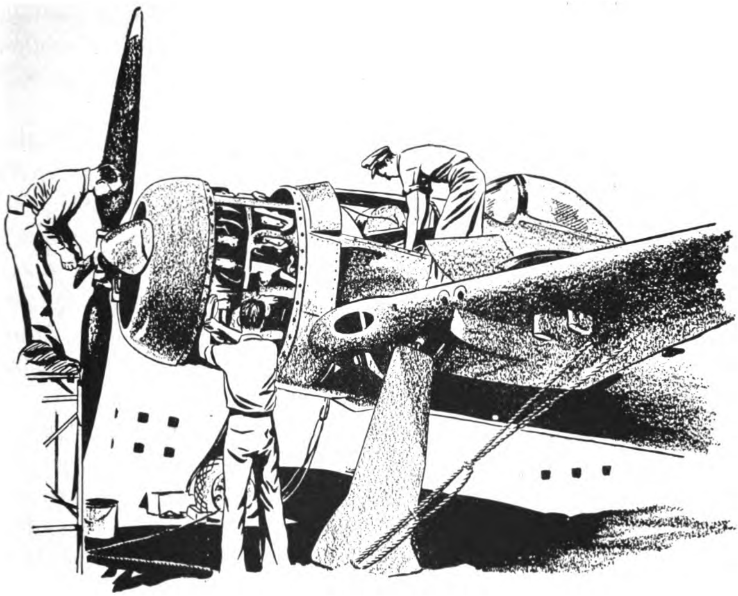
This is accomplished by the use of built-in fans and the addition of blast tubes which carry cooling air to the generator from the slipstream. Some generators use spun glass insulation which does not break down under extreme temperature. Such improvements have made it possible for the modern generator to more than double the output of the older aircraft generators without any corresponding increase in weight.

Under normal flight conditions, current consumption is not great. On the other hand, large quantities of current are needed for starting, for landing lights, and for the operation of landing gear and flaps through short periods of time on planes using electrically-operated units. Consequently, the generator must be capable of very quickly recharging a practically exhausted battery.

The generator on an airplane engine is operated by a shaft driven by the main accessory drive shaft through a gear arrangement. A regulating mechanism takes care of the intermittent load requirements while at the same time preventing overcharge of the battery. This mechanism is contained in a separate control box.

QUIZ

1. What Navy Training Course would you consult for information on aircraft carburetors?
2. What type of starters are most used in modern naval aircraft?
3. What is inertia?
4. What are the three types of electric starters?
5. How does a hand inertia starter operate?
6. What is the chief difference between an electric inertia starter and a hand inertia starter?
7. Why are most engine-driven generators direct-current generators?
8. How may the output of a generator be increased without increasing its size or weight?
9. What factor limits the power output of a generator?



CHAPTER 5

LUBRICATION AND COOLING

When one dry metallic surface is moved over another, a high resistance (friction) is encountered which results in the generation of heat and excessive wear. Imagine what would happen to an engine if the many moving parts were not lubricated! Surfaces would be rapidly worn away. The temperature of the parts would rise, dangerously expanding them. The friction would result in a great loss of power, and you soon would need an engine overhaul or replacement.

If a thin film of oil separates two metallic surfaces, the wear on the metal is practically eliminated, and heat is reduced to a minimum.

LUBRICATION

The oil system of an aircraft engine is designed to supply proper lubrication to all moving parts of the engine, and to aid in dissipating engine heat. There are two general types of

aircraft engine oil systems—the wet sump and the dry sump. Since the wet sump type carries the oil supply in the engine crankcase, it is not suitable for radial-type engines, and will be discussed only briefly in our study.

The DRY SUMP type of aircraft engine oil system carries the main supply of oil in an external oil tank. The oil is pumped through the engine by an OIL PRESSURE PUMP and returned to the oil tank by an OIL SCAVENGER PUMP.

Circulation of the oil through a series of strainers or filters cleans the system of dirt, sludge, and other foreign matter. In addition, a MAGNETIC OIL DRAIN PLUG is placed in the bottom of the oil pumps to catch and remove loose particles of metal from the oil.

Since aircraft engines operate under extreme temperatures and develop a high power output, oil must be supplied to the engine at specified pressures and temperatures. This is accomplished by means of OIL PRESSURE RELIEF VALVES and OIL TEMPERATURE CONTROL SYSTEMS which maintain the required conditions.

SUPPLY AND RETURN

As illustrated in figure 27, oil travels from the OIL TANK through lines to the OIL PRESSURE PUMP, and is cleaned before entering the engine. An OIL SUMP in the bottom of the engine acts as a reservoir to catch the oil after it has passed through the engine. The oil is picked up and pumped back to the oil tank by the SCAVENGER PUMP. An OIL PRESSURE RELIEF VALVE controls the oil pressure to the engine. Located in the cockpit is an OIL PRESSURE GAGE and an OIL TEMPERATURE GAGE for indication of pressure and temperature of oil entering the engine.

OIL TANKS

Oil tanks are usually mounted in a padded cradle on the forward side of the engine firewall. The tanks are generally constructed of stainless steel or aluminum alloy. Self-sealing oil tanks, almost identical with the self-sealing fuel tank, have been used on some installations.

Oil tanks are built to withstand an internal pressure of at

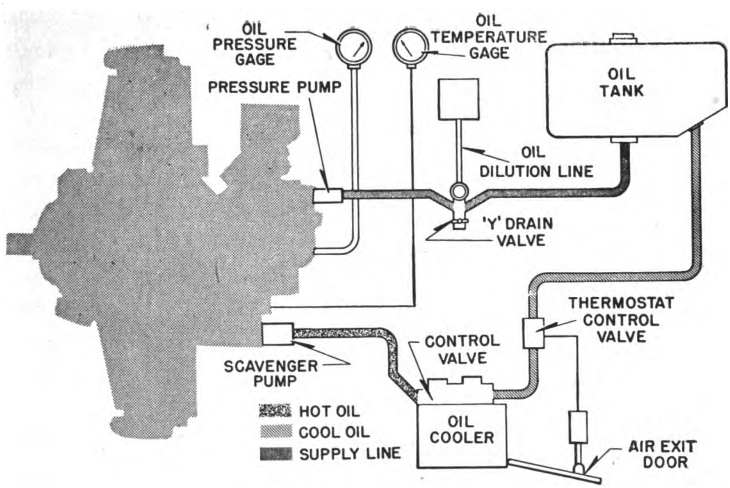


Figure 27.—Oil supply and control.

least 3 pounds per square inch. Tanks of more than 15 gallons capacity may be divided so that only one-third of the oil circulates. As this oil is consumed, it is replaced by oil from the larger section. BAFFLE PLATES are incorporated in larger oil tanks to reduce surging, as well as to reinforce the tank.

An oil filler cap is generally fastened to the filler neck of the tank by means of a safety chain, except when the oil sounding rod is mounted on the cap. In this latter instance, the filler cap is secured in position by means of a safety locking device. The oil filler cap is usually painted yellow, and has the capacity of the oil tank painted or stenciled upon its surface.

The oil tank SOUNDING ROD is a measuring stick, calibrated in gallons and used to determine the quantity of oil in the tank. The "full" mark is never located at the top of the rod—this is to allow for expansion of the oil. OIL TANKS MUST NEVER BE FILLED ABOVE THE "FULL" MARK.

An OIL STRAINER is mounted directly below the filler neck to strain the oil when the tank is being filled. An additional strainer is generally incorporated in the tank to strain oil returning from the oil coolers. A schematic diagram of an oil tank is illustrated in figure 28.

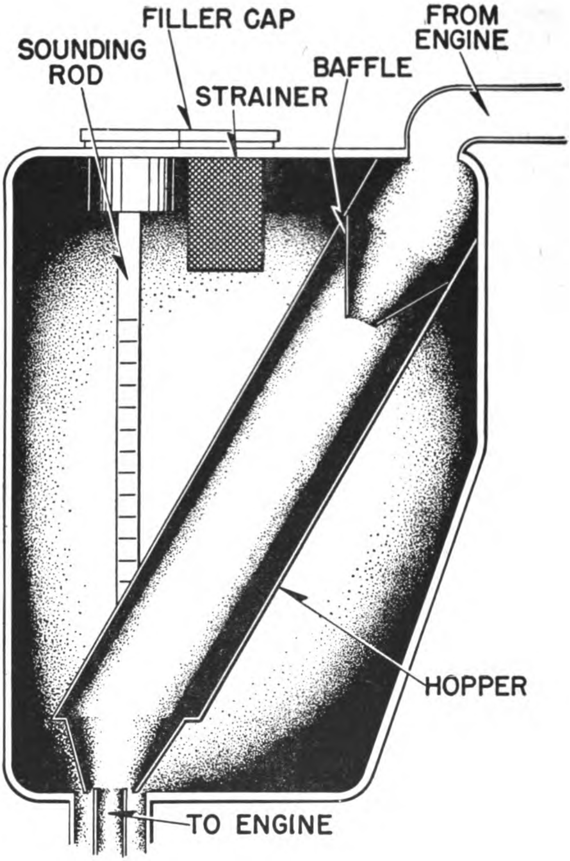


Figure 28.—Schematic diagram of an oil tank.

The majority of oil tanks are fitted with a sump at the bottom in order to trap water or sediment in the oil.

A circular SWIRL CHAMBER may be incorporated in the tank to separate air and foam from oil returning from the engine.

OIL COOLER AND CONTROL VALVES

The oil cooler is designed to dissipate the heat from the oil to the atmosphere. The amount of heat dissipated, or the regulating of the temperature of the oil flowing through the

engine, is controlled by various types of valves. Air flow through the cooler is controlled by manually, hydraulically or electrically operated shutters or exit flaps.

The cooler is built with two concentric cylinders of sheet brass. The inner cylinder is approximately 1 inch smaller in diameter than the outer cylinder, and contains the cooling core of the unit. The passage between the two cylinders provides a pathway by which the oil may be permitted to bypass the core. Figure 29 illustrates the arrangement of the copper tubes which carry cooling air through the core. Oil which passes through the core is guided by baffles so that it flows

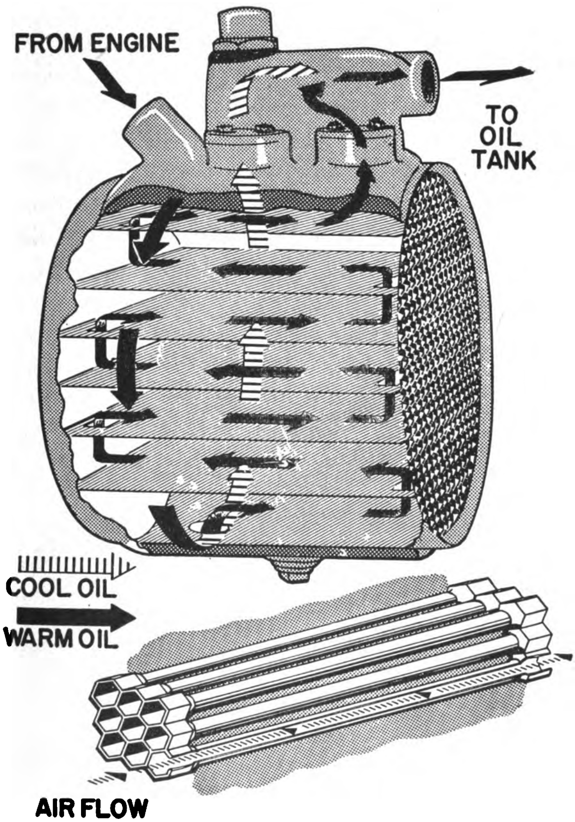


Figure 29.—Oil cooler assembly.

around the tubes and the length of the core several times. The tubes have hexagonal-shaped ends which form the honeycombs in both ends of the cooler. Tube ends are soldered together to prevent leakage between them.

An oil cooler control valve, mounted on the shell of the oil cooler, directs the flow of oil either through or around the cooling unit (core) of the oil cooler. In some cases, an aluminum casting with two built-in passages and a thermostatic element may be used, as shown in figure 30. The oil flows around a flexible copper bellows regardless of which path it follows through the cooler.

The bellows contain an activating fluid which expands when heated, and a spring which tends to compress the bellows. A spring in the cap of the unit acts as a spring-loaded relief valve when the oil is hot or in the event of the bellow's failure. When cool oil from the engine flows into the oil cooler assembly, the thermostatic oil cooler valve is open. Most of the oil flows around the core between the inner cylinder and the outer cylinder, through the path of least resistance, and is bypassed through the valve to the outlet without cooling.

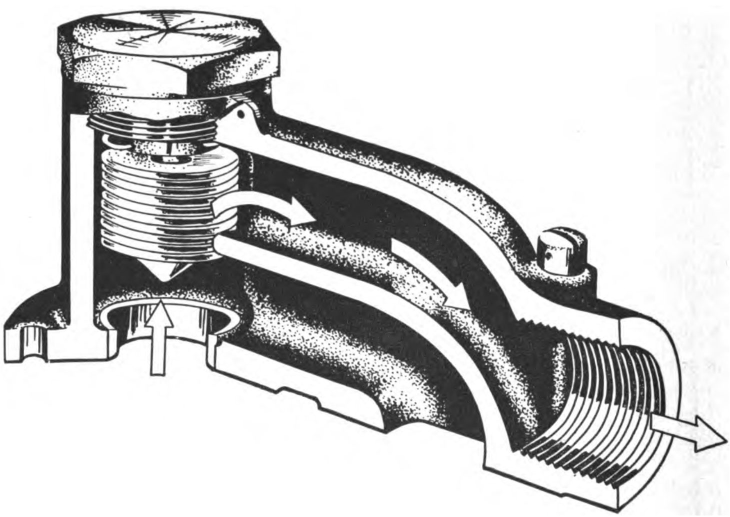


Figure 30.—Thermostatic oil cooler valve.

OIL PUMPS

The dry sump type oil system requires two or more pumps for its operation. The oil is pumped from the oil tank to the engine by means of a gear-type OIL PRESSURE PUMP. After lubricating the engine, the oil falls to the sump at the bottom of the engine from where it is pumped back to the tank by an OIL SCAVENGER PUMP.

Oil leaving the tank for the engine is comparatively cool and free from air or foam. Oil leaving the engine, however, is hot and contains a considerable quantity of air which has been churned into it by the action of pistons and master rod assembly. The air increases the total volume of oil to be pumped back to the tank. For this reason, it is necessary to use a larger scavenger pump in order to handle the increased volume.

GEAR-TYPE PUMPS are used almost exclusively for engine oil systems. Oil enters the pump and passes around the gears where it is forced out under pressure into the engine. An oil pressure relief valve may be installed either on the pump or in the oil pressure line from the pump.

One or more high-capacity, gear-type scavenger pumps are required to pump oil from the various sumps back to the tank. Oil pressure and scavenger pumps are usually incorporated into one unit with a single drive shaft. However, separate independently driven units may be used. All types of engine oil pumps are provided with an oil seal device which prevents oil leakage from one sump into the other, or into the engine.

PRESSURE CONTROL VALVES

In order to relieve excessive pump pressures in the oil system, an OIL PRESSURE RELIEF VALVE (fig. 31) is incorporated in the pressure lines.

Increasing the compression on the relief valve springs by means of the adjusting screw increases the operating pressure and consequently the pressure required to lift the relief valve off the seat.

When engine oil is cold, it has such high viscosity, or resist-

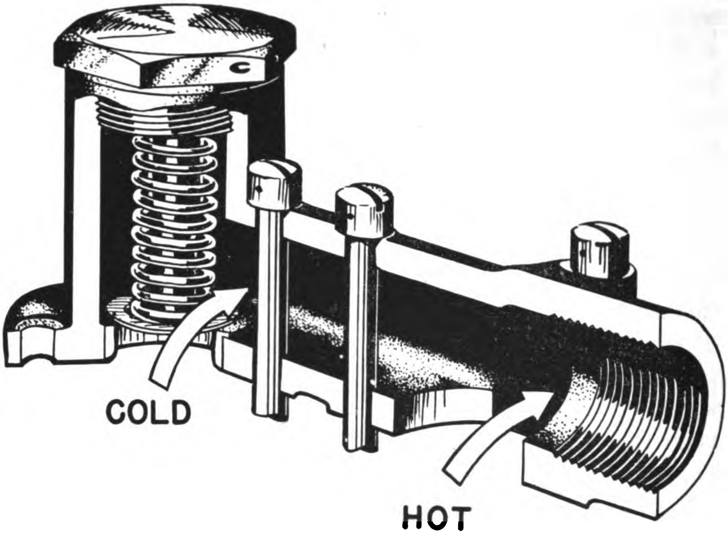


Figure 31.—Oil pressure relief valve.

ance to flow, that it may not properly lubricate the engine. To overcome this fault, a COMPENSATING-TYPE pressure relief valve (fig. 32) may be installed in the oil system. This valve permits starting pressures as high as 400 pounds per square inch and insures an adequate supply of oil to the engine immediately upon starting. This is accomplished through use of a thermostat which regulates the operation of a second high-pressure relief valve spring by means of oil pressure upon a piston.

When oil temperatures are below 40° C., both the low- and high-pressure relief valve springs exert combined pressures upon the relief valve to keep oil pressure around 400 p.s.i. As oil temperature approaches 40° C., the thermostat expands, permitting oil to flow through the static line to the piston which releases the high-pressure spring from the relief valve. This action permits oil pressure to return to normal.

In order to protect the engine oil system from stoppage caused by a clogged strainer or the inability of cold oil to pass through the fine mesh of the strainer, a spring-loaded BYPASS

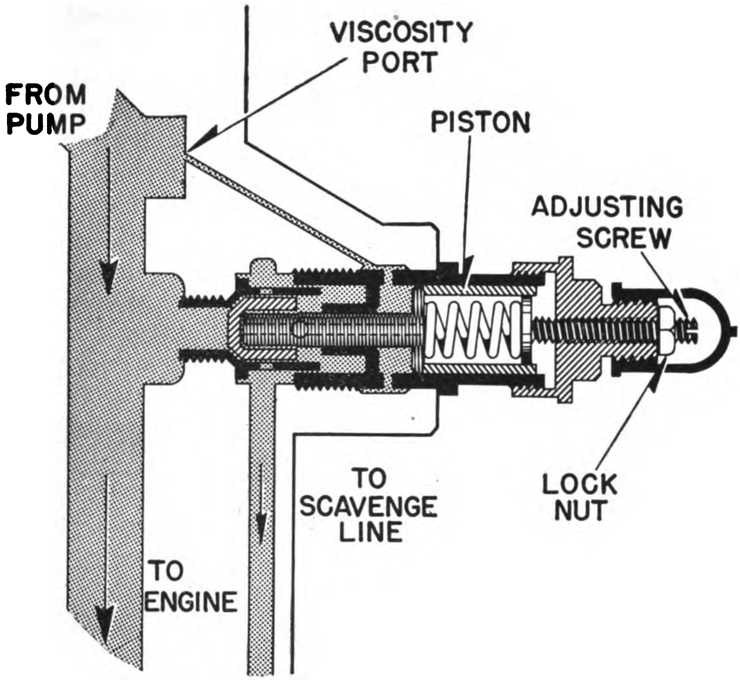


Figure 32.—Compensating-type relief valve.

VALVE is located at the main strainer. This valve is controlled by the differential in pressure between the inlet and outlet sides of the strainer.

OIL STRAINERS AND FILTERS

Since solid particles of foreign matter in oil may damage an engine or cause complete engine failure, a series of strainers or filters must be incorporated in the oil system.

The MAIN STRAINER, which is generally located at the outlet side of the oil pressure pump, strains the oil before it enters the engine. It is constructed of a 60- to 80-mesh bronze wire screen. The fine mesh screen must be removed, inspected, and cleaned at regular intervals.

Another important part of the oil supply system is the OIL

FILTER. As the name implies, the oil filter is simply a device for cleaning the oil. One commonly used type—the Cuno filter, shown in figure 33—consists of a number of disks spaced very close together. The oil, on its journey between the engine and the tank, must pass between these disks. The disks are so close together that any grit or dirt in the oil is screened out and dropped into a sediment bowl in the bottom of the cleaner. In some installations the space between the disks is cleaned automatically, while in others it must be done manually at frequent intervals.

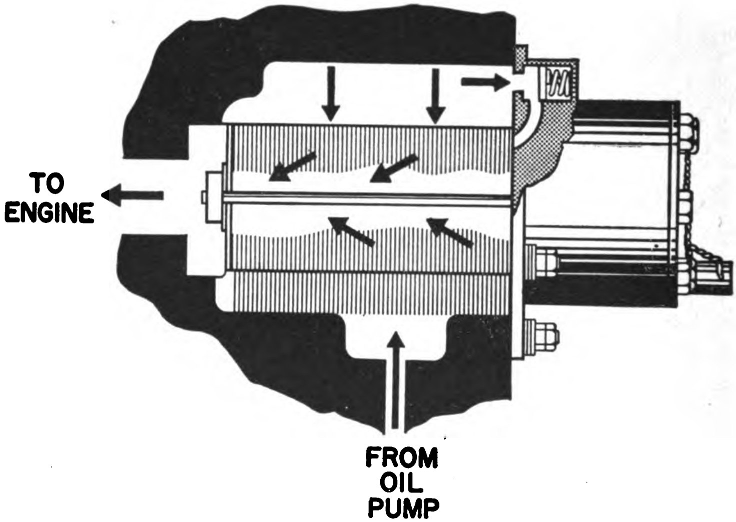


Figure 33.—Cuno filter.

As oil passes through the engine oil sump, the sump strainer, which is of fairly large mesh, catches particles of dirt or carbon, and the magnetic drain plug catches particles of iron or steel resulting from wear within the engine.

OIL TEMPERATURE AND PRESSURE GAGES

The actuating unit of the oil temperature gage is generally located in the oil inlet, and is connected to the temperature gage head in the cockpit. Some installations, however, employ gages in both the oil inlet and the oil outlet lines.

There are two types of oil temperature gages in common use—the VAPOR type and the ELECTRIC type. The vapor-type temperature gage consists of a bulb connected to a Bourdon-type gage in the cockpit by means of a capillary tube. The bulb unit is partially filled with a volatile liquid such as ether or alcohol, and the entire unit may be compared to a steam boiler connected to a steam pressure gage.

When heat is applied to the bulb, the volatile liquid generates pressure in direct ratio to the amount of heat applied. The pressure is transmitted through the capillary tubing to the cockpit gage unit which is calibrated to read in terms of centigrade temperature.

The electric type of oil temperature gage consists of either a thermocouple unit and a suitable meter, or a resistance unit coupled through a Wheatstone bridge to a suitable meter. In either case, the gage head unit is always a sensitive electric meter calibrated to read in terms of centigrade temperature. Operation of the electric oil temperature gage which uses the resistance bulb unit is based upon the principle that the conductivity of an element of known resistance varies with the temperature.

The oil pressure gage is used to provide the pilot with a reading, in pounds per square inch, of the oil pressure being supplied to the engine. A conventional Bourdon-type gage head in the cockpit is connected to the engine oil line at some point between the oil pressure pump and the engine. The pressure orifice in the gage is limited to the size of a No. 60 drill in order to protect the gage from pressure surges and the consequent rapid fluctuation of the gage hand.

The engine gage unit consists of an oil pressure gage, a fuel pressure gage, and an oil temperature gage.

RADIAL ENGINE LUBRICATION

The semi-diagrammatic drawing in figure 34 traces the lubrication in a radial engine of fairly simple construction.

Examination of this diagram will disclose that the oil system begins with the tank. The oil is drawn in by the pressure pump (P)—usually a gear pump driven by the crankshaft.

The oil is discharged from the pressure pump into a passage which leads into the hollow crankshaft (C). It is usually introduced into the engine at the rear bearing.

This bearing is provided with an annulus (groove) entirely around its interior. At the point where this groove surrounds the crankshaft, holes are drilled from the outside of the crankshaft into its hollow interior. The annulus is kept continuously filled with oil by the pump. Since this oil is under pressure, it is forced through the holes drilled in the crankcase into the interior of the shaft.

Other passages may lead from this annulus to the various accessory drives, supercharger gearing, and other points re-

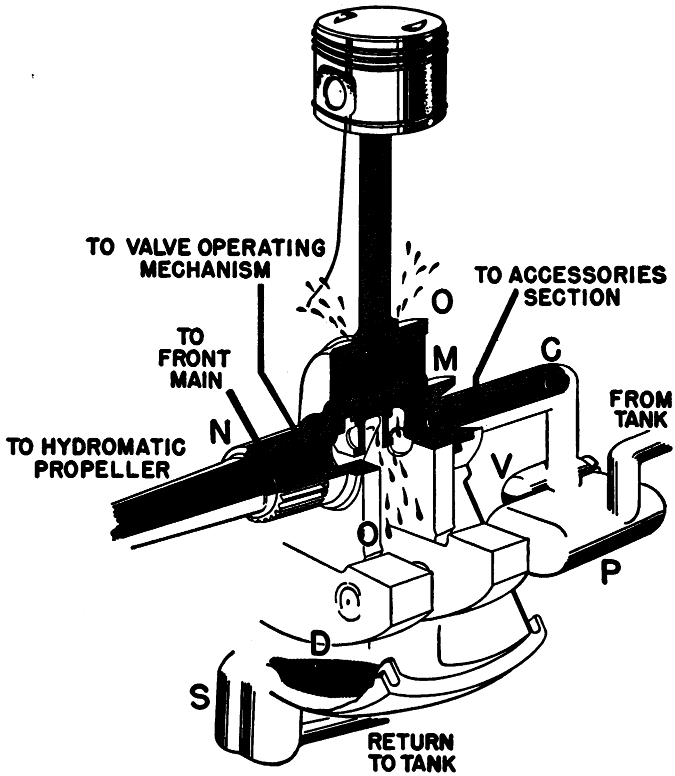


Figure 34.—Oil system of a radial engine.

quiring pressure lubrication. The oil can escape from the crankshaft only by being forced out between the bearing surfaces. The pump, however, is capable of building up high pressure and supplying more oil than the engine needs. If too much oil is supplied, the excess will work up into the combustion chamber and foul the spark plugs, as well as producing an undue amount of carbon on cylinder heads and pistons. Accordingly, the pressure of the oil must be controlled.

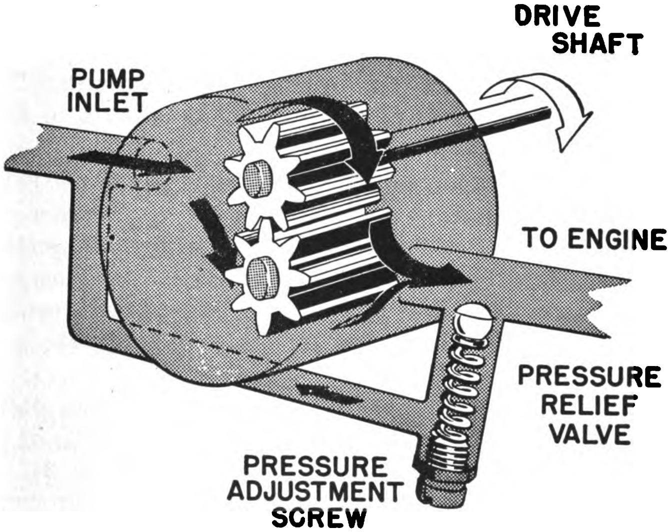


Figure 35.—Oil pump and relief valve.

Such control is possible through the relief valve, indicated as (V) in figure 34. As shown in figure 35, this device is simply a spring-loaded ball or plate. The valve may be adjusted by increasing or decreasing the compression on the spring. The normal operating position of the valve is partially open. If the pressure drops, the valve closes; if the pressure rises, the valve opens.

Occasionally, a small particle of foreign matter under the valve will hold it open and prevent it from building up the required pressure. Accordingly, if the oil pressure suddenly

drops, one of the first items you should inspect is the pressure relief valve.

The master rod bearing is lubricated by means of holes drilled from the outside of the crankpin to the interior, as shown at (M) in figure 34. The oil is forced through these holes and between the bearing surfaces. It is thrown off in fine drops, or spray, by the rapidly rotating crankshaft, as indicated at (O) in figure 34. Other holes through the crankpin line up with holes in the master rod bearing which lead through the knuckle pins. Thus, these pins are provided with lubrication, and the excess oil that works out around the knuckle pin bearings is also thrown on the cylinder wall. This process lubricates the pistons, the cylinders, and all of their moving parts.

From the crankpin, a passage leads to the forward portion of the crankshaft, as indicated at (N) in figure 34. Oil from this passage is used to lubricate moving parts in the nose section, and by means of an annulus in one of the front bearings, may be led to the rocker arms and to the propeller governor control. Naturally, this oil is used only if a hydraulically operated propeller is installed.

The oil thrown on the cylinder walls is forced out of the bearings in the nose section, and runs down the walls of the crankcase or falls, as indicated by the arrows in figure 34, and eventually collects in the sump. Here it passes through a sump strainer (D), and is picked up by the scavenger pump (S) which returns it to the tank.

OIL DILUTION

The difficulty in starting an aircraft engine in cold weather results from the high cranking torque (resistance to turning) of a cold engine. This resistance is caused by the viscous, sticky drag of the oil, particularly between the pistons and cylinder walls. You can readily see why thinning the oil before the engine is stopped in cold weather will greatly reduce the cranking torque and facilitate the next starting.

A system of OIL DILUTION has consequently been developed in order to thin out the oil before stopping an engine. In such

a system, a line connects the fuel pressure line to a special Y draincock in which a spring poppet valve is installed. This valve is manually operated from the cockpit.

Before the engine is stopped in cold weather, a small amount of fuel is allowed to enter the oil inlet line by holding the dilution control open for a short time with the engine operating. The diluted oil then replaces the heavy oil throughout the entire engine, making the engine easier to start in cold weather.

For complete, detailed information on the lubrication system of any specific engine, reference must be made to the lubrication chart in the technical publication for the engine involved.

COOLING

You have seen that the power developed by an engine is directly proportional to the heat of combustion. It is essential, however, that the operating temperature of an engine be maintained within safe limits because of the limitations of present-day fuels—excessive heat causes detonation and loss of power. Cooling also results in energy loss, generally about 30 percent of the total heat-energy generated. This loss cannot be reduced to any great extent without decreasing the reliability of engine operation.

The AIR-COOLED ENGINE is usually lighter, in relation to its horsepower, than the liquid-cooled engine, since it has no jackets, liquids, or radiators. The simplicity of the system makes it practically free of cooling failures, and the individual cylinder arrangement makes it more easily accessible for repair. It is also less vulnerable to gunfire in military aircraft.

The LIQUID-COOLED ENGINE has a smaller frontal area that lends itself to better streamlining in the nose. This permits greater speed, and gives the pilot increased visibility. The liquid-cooled system also has a better temperature control and makes possible more definite temperature readings, so that cooling of the entire engine may be quickly analyzed.

AIR COOLING

The principle of air cooling is simple. When the cool air from the propeller stream of a plane comes in contact with hot

metal cylinders, the heat is dissipated. The greater the surface exposed, the quicker the cooling process works; and the faster the cool air is blown against the surface, the more effective is the air cooling.

As you already know, air-cooled cylinders are made up of steel barrels and light alloy heads heavily finned for strength and for adequate cooling. Exposed fin areas have been increased from approximately 600 square inches on the old type of cylinder to 2,800 square inches on the new-type cylinder. This increase in surface area takes care of the extremely high combustion temperatures permitted with the use of improved fuels.

AIR DEFLECTORS, or PRESSURE BAFFLES, are installed in high-

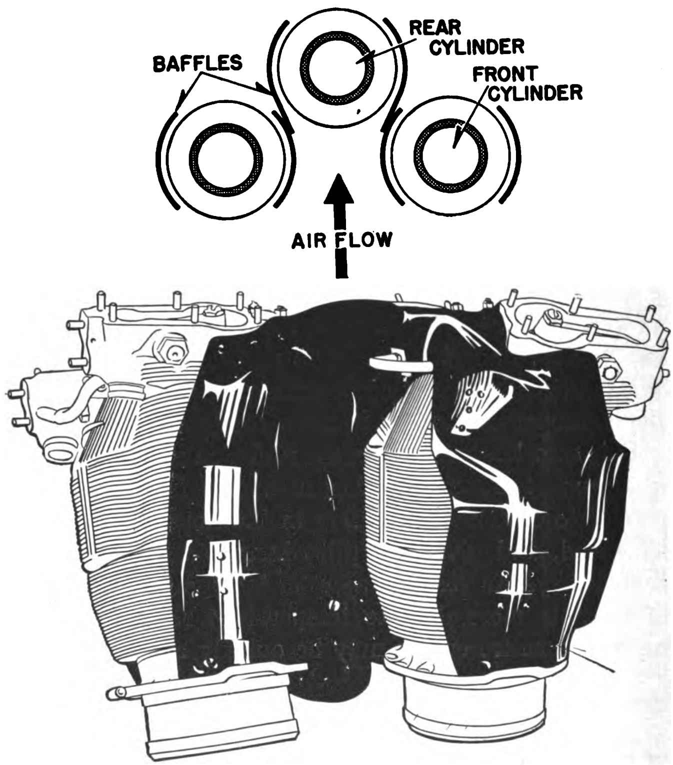


Figure 36.—Pressure baffles for twin-row engine.

performance aircraft engines to more effectively utilize cooling air. Figure 36 shows a typical pressure baffle system for a twin-row engine. As this illustration demonstrates, the baffles guide the air flow and increase its velocity over the cooling fins.

Pressure baffles, however, may result in inadequate cooling during ground operation. It is important that cowl flaps be fully open during ground operations.

Streamlined full depth NACA (National Advisory Committee for Aeronautics) cowling around the outside circumference of the cylinders also improves cooling efficiency. Such a cowling consists of a hood, or ring, and a portion of the body behind the engine.

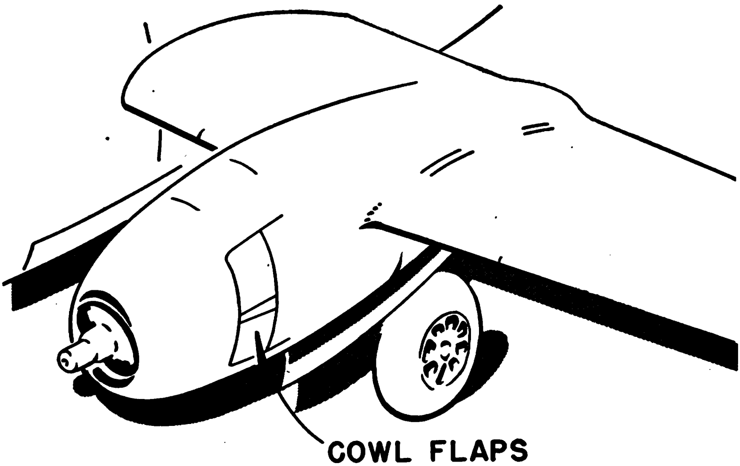


Figure 37.—Cowl flaps and NACA cowling.

The cooling efficiency will vary with the speed of the aircraft or velocity of the air flow. As a general rule, however, cooling designed for efficiency at high air velocities is somewhat inefficient at low air velocities, particularly when the engine is being operated on the ground. To overcome this difficulty, controllable flaps may be placed in the trailing edge of the NACA cowling, as shown in figure 37.

Some air-cooled engine installations in low-performance airplanes have a cowling over the front crankcase section. This

provides a means of control by which the airflow can be circulated around the crankcase in warm weather, and partially closed off in cold weather.

The cylinder head temperature is measured with a thermocouple mounted at the spark plug, as shown in figure 38. Essentially, the thermocouple is a junction of two different metals. When the junction is heated, an electromotive force is developed in proportion to the degree of temperature. The strength of this electromotive force is measured by a sensitive voltmeter which is calibrated to be read in degrees of temperature.

This type of thermocouple is usually installed in place of the standard spark plug gasket in the particular cylinder which proves by test to be the hottest under most operating conditions. Where an attachable spark plug shield is used, the thermocouple gasket is installed between the shield and cylinder head. The two thermocouple wires are of copper and constantin, each wire properly designed for correct installation on the cylinder temperature indicator in the aircraft cockpit.

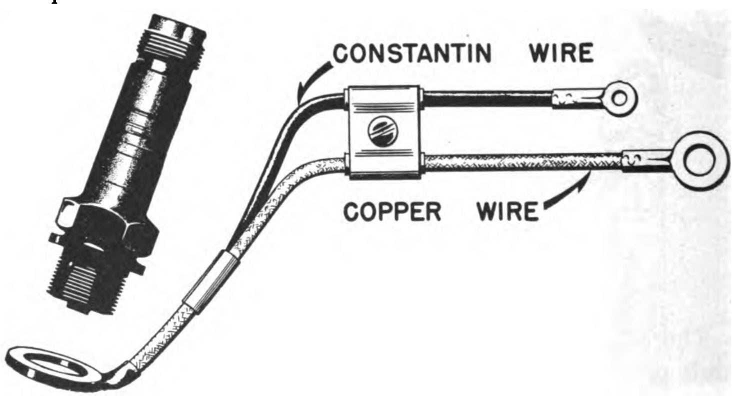


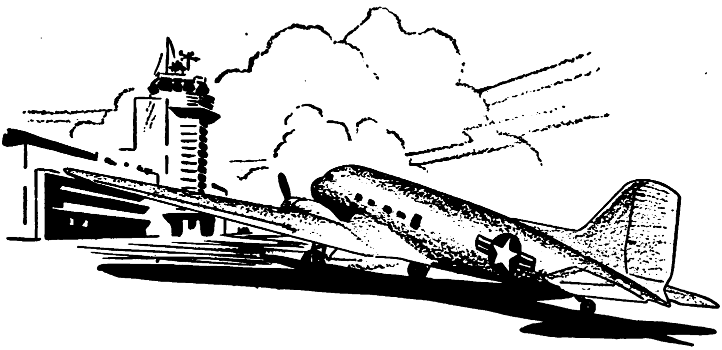
Figure 38.—Spark plug-type thermocouple.

Cylinder-base temperatures may also be measured with a thermocouple, the two wires being embedded in the cylinder-barrel flange and connected to the indicator in the cockpit.

You should consult operating instructions for specific temperature limits for various engines.

QUIZ

1. Why is it dangerous to have the oil pump supply more oil to the engine than needed for proper lubrication?
2. How and when is engine oil diluted? Why?
3. What disadvantage results from the use of pressure baffles during ground operation of aircraft engines?
4. What is the purpose of the thermocouple mounted at the spark plug?
5. There are two general types of aircraft engine oil systems—the wet sump and the dry sump. What type is used in radial engines?
6. What pumps are used with the dry sump type oil system?
7. What device is used to relieve excessive pump pressure in the oil system?
8. What devices are included in the oil system to keep the oil clean?
9. What type gage is used to measure oil pressure?
10. Which would you expect to be lighter, an air-cooled or a liquid-cooled engine of the same horsepower?



CHAPTER 6

PRATT & WHITNEY TWIN WASP (R–1830) ENGINE

The model R–1830–94 engines (figs. 39, 40, 41), manufactured by Pratt & Whitney, are 14-cylinder, two-row radial, air-cooled aircraft powerplants with a single-stage, two-speed supercharger. To facilitate description, these engines are divided into five sections—front section, power section, blower section, intermediate rear section, and rear section. Your study of these engines will consider these sections in the above order.

FRONT SECTION AND SUPPORT PLATE

The FRONT CASE houses the propeller shaft and the reduction gearing, as illustrated in figure 42. A liner in the front end of the case carries a ball bearing which receives the thrust from the propeller shaft. The two magnetos and the propeller governor are mounted on pads attached to the exterior of the case. A timing hole in the side of the case is provided so that you may observe the alignment of timing marks on the reduction drive gear when checking timing.

The REDUCTION GEARING is of the bevel planetary type, and the pinion cage is integral with the propeller shaft. The reduction gear drive is coupled to the front end of the crankshaft by three splined couplings. This gear is supported on the propeller shaft by a ball bearing. The reduction gear drive fixed gear is splined to an anchor fastened in the front of the

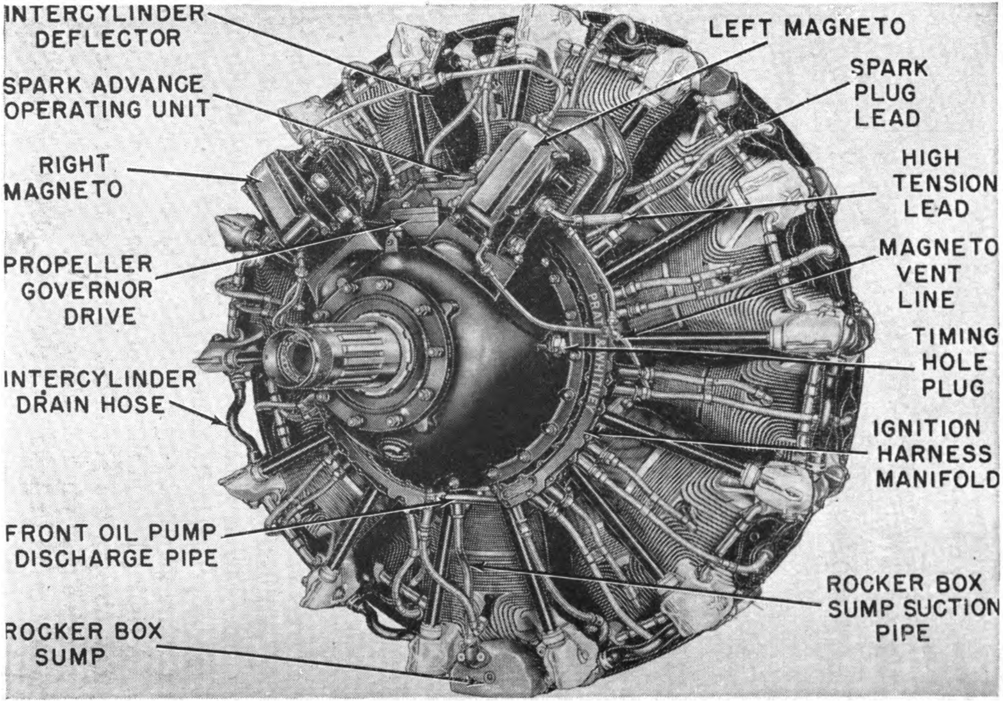


Figure 39.—Left front view of R-1830 engine.

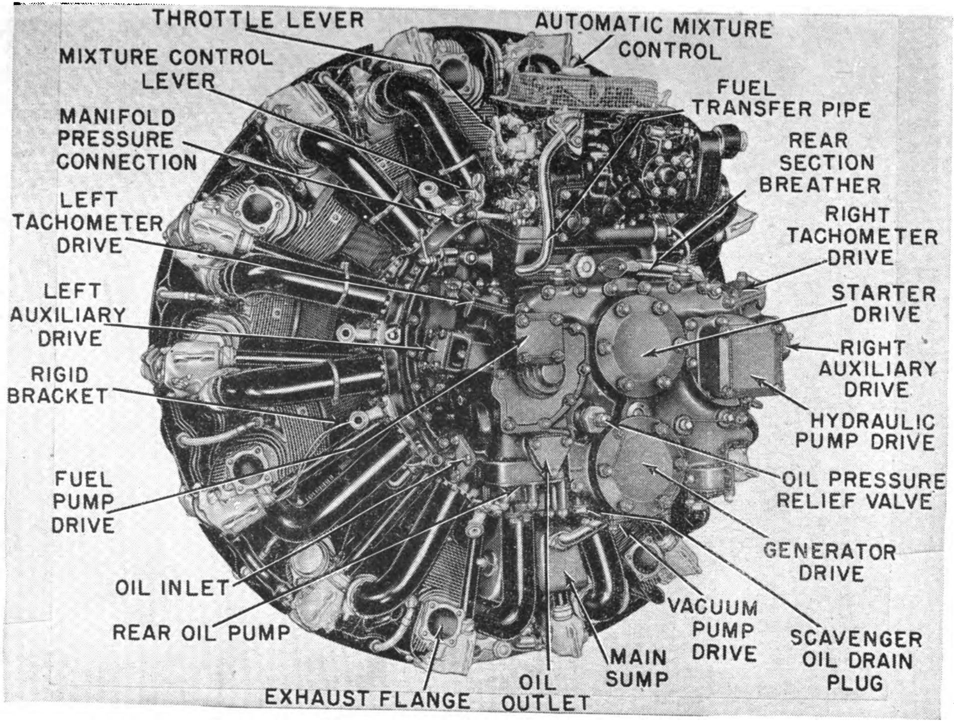


Figure 40.—Left rear view of R-1830 engine.

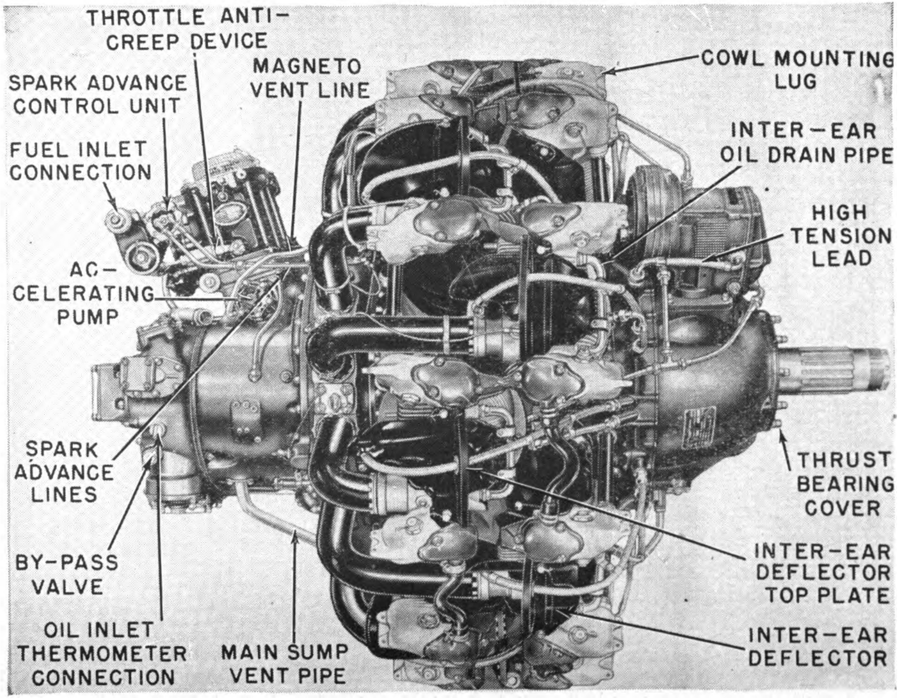


Figure 41.—Right side view of R-1830 engine.

front case, and is supported on the propeller shaft by a ball bearing.

Six bevel pinions with leaded bearings are mounted in the pinion cage, and mesh with the drive and fixed gears. An angular contact thrust bearing takes the outward thrust of each pinion. The propeller shaft is supported at the front end by the thrust bearing in the front of the front case. The rear end of the propeller shaft is supported by two roller bearings. The reduction-drive front coupling is fitted between these bearings. The outer portion of these two bearings is supported in a liner in the support plate.

The SUPPORT PLATE carries the intermediate gears which drive the front oil pump, the propeller governor, and the magneto drive gears, as illustrated in figure 43. The spark advance piston is housed in two bosses on the front of the support plate. The cam bearing support is attached to the rear of the support plate by studs and nuts. The rear end of the front oil pump is supported in a hole in the support plate.

Each of the MAGNETO DRIVE GEARS is supported by two ball bearings—one in the front case, the other in a bearing support attached to the case. The timing of the magnetos to either the 25° normal spark advance or a 32° cruising spark advance is determined by the position of the spark advance pinions. Two spark advance pinions are mounted on a bracket in each magnet intermediate drive bevel gear train. In each gear train, the magneto intermediate drive bevel gear is driven by the spark advance pinion gear acting on the spark advance pinions, as demonstrated in figure 43.

The position of the two pairs of SPARK ADVANCE PINIONS determines the timing of the two magneto intermediate drive bevel gears. This also determines the timing of the magneto drive gears in relation to the spark advance pinion drive gears. These latter gears are splined to the magneto intermediate drive spur gears. As these spur gears are driven by the upper cam reduction gear, their timing remains fixed in relation to the crankshaft.

The spark advance pinion position is shifted automatically from normal to cruising and back to normal by the spark ad-

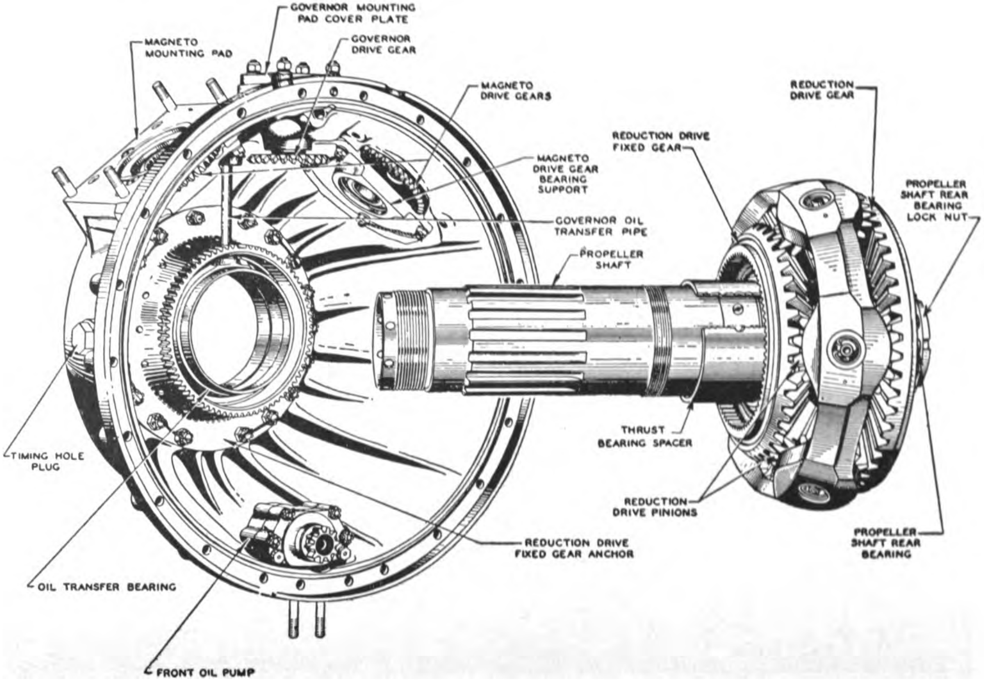


Figure 42.—Front case and reduction gearing.

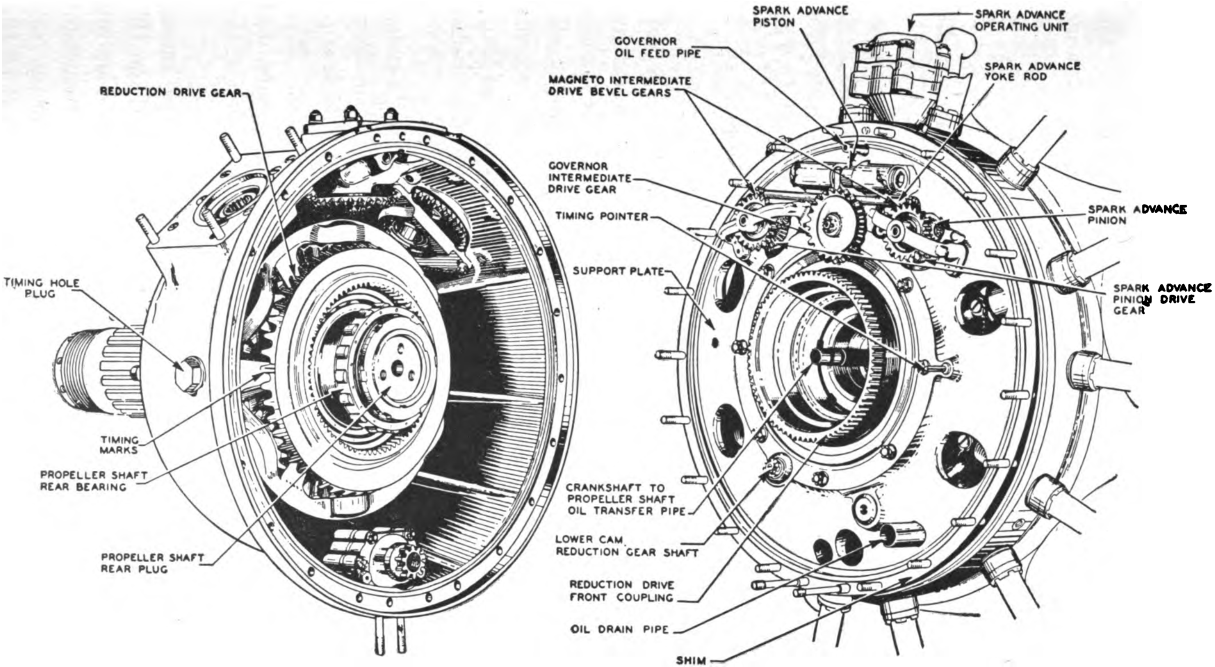


Figure 43.—Front section and support plate.

vance system. This is equally the case when the engine speed is advanced or decreased through the cruising range.

The spark advance operating unit is mounted on the top of the front crankcase. This unit is connected by pipes to the blower rim case, the blower throat, and the spark advance control unit on the carburetor. The operation of the automatic spark advance system is effected by the differential in blower rim pressure and blower throat pressure.

The GOVERNOR DRIVE GEAR is supported in a bushing in the front case, and is driven by the governor intermediate drive gear. This drive gear is splined to the front end of the upper cam reduction gear.

The FRONT OIL PUMP DRIVE GEAR is driven by an intermediate gear which is supported in a bushing in the support plate. The intermediate gear is driven by the front cam.

POWER SECTION

The three sections of the CRANKCASE are bolted together. Around the outside of the assembly are 14 cylinder mounting pads. Liners in the center and rear sections of the crankcase support the crankshaft center and rear bearings. The crankshaft front bearing is supported by the front cam bearing which is seated in the front section of the crankcase, as illustrated in figure 44. The front and rear sections of the crankcase contain bosses for the tappet guides.

The CAM GEAR TRAINS operate valves through single-piece, double-track cams supported on bronze bearings. The front cam bearing is splined to the cam bearing support, and is supported in the bore of the front section of the crankcase. This is illustrated in figure 44. The rear cam bearing is mounted on a circular shelf which is integral with the rear section of the crankcase, as shown in figure 45.

Each cam is driven by two cam reduction gears. The FRONT CAM REDUCTION GEARS are driven by the external teeth on the reduction drive on the intermediate coupling. This coupling is attached to the front end of the crankshaft by the reduction drive gear coupling. The REAR CAM REDUCTION GEARS are driven by the crankshaft rear gear which is attached to the rear end of the crankshaft.

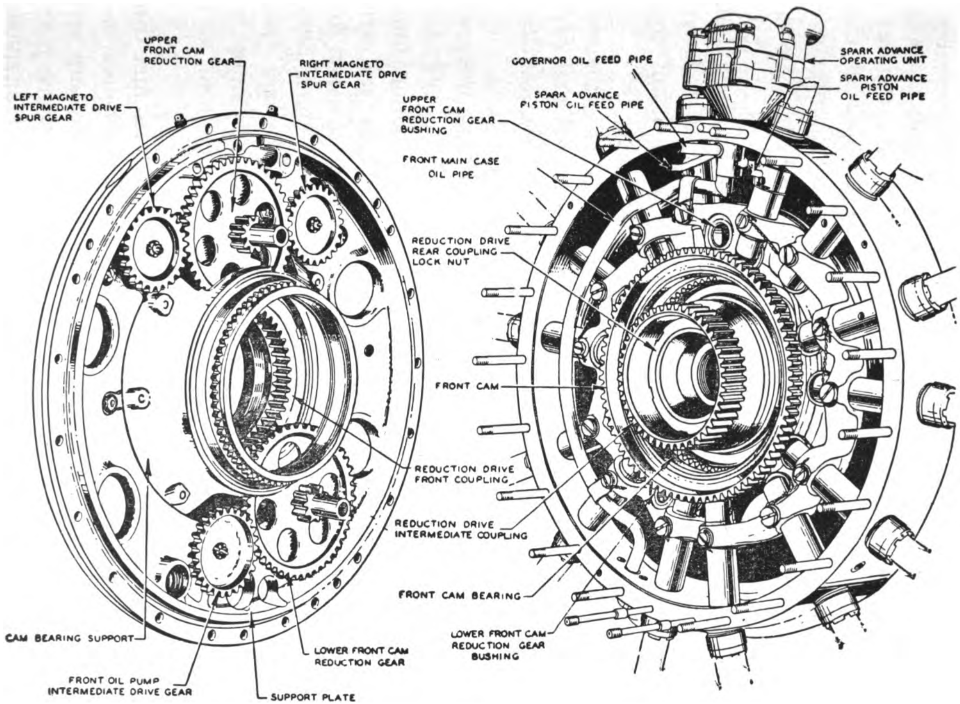


Figure 44.—Support plate and front cam compartment.

The front cam reduction gears are supported by bushings in the support plate and the front section of the crankcase. The rear cam reduction gear bushings are in the rear section of the crankcase and the blower case.

The single-piece CRANKSHAFT has two crankpins to which the master rods are attached. The weight of the reciprocating master rod and piston assemblies is balanced by two counterweights, one of which is riveted to the front cheek of the crankshaft. A flyweight, serving as a damper to suppress torsional vibration, is housed in a liner fitted in the rear cheek and its counterweight.

The crankshaft is supported by three roller bearings mounted in the front, center, and rear sections of the crankcase. Some engines incorporate a plain journal bearing in place of the roller bearing in the center section of the crankcase.

The MASTER RODS are located in No. 5 and No. 12 cylinders. Each master rod assembly consists of a master rod and cap (bolted together), six I-section articulated rods, six knuckle pins, and a two-piece leaded master rod bearing.

The CYLINDERS consist of cylinder heads with their integral cooling fins. These fins are screwed and shrunk to cylinder barrels which have aluminum muffs and deep cooling fins. Rocker boxes are provided with cowl mounting lugs, and are integral with the cylinder heads. Each head incorporates an inlet and an exhaust valve guide and seat, two spark plug bushings, and four rocker shaft bushings in the rocker box walls. The oil drain line between each pair of rocker boxes is permanently assembled on the front of the cylinder head, and supports the inter-ear deflector.

CYLINDER DEFLECTORS are mounted on the cylinder and the cylinder heads. They direct cooling air through the spaces between the fins on the cylinders. The inter-ear deflectors are provided with blast tubes to direct air on the rear spark plug lead elbows, and have separate top plates to hold the rear spark plug lead grommets. Sealing strips on the edges of the cylinder deflectors and the edges of the rocker box covers increase the efficiency of the cooling system.

The VALVE MECHANISM functions as follows: The valves are operated by rockers supported on shafts in the rocker boxes.

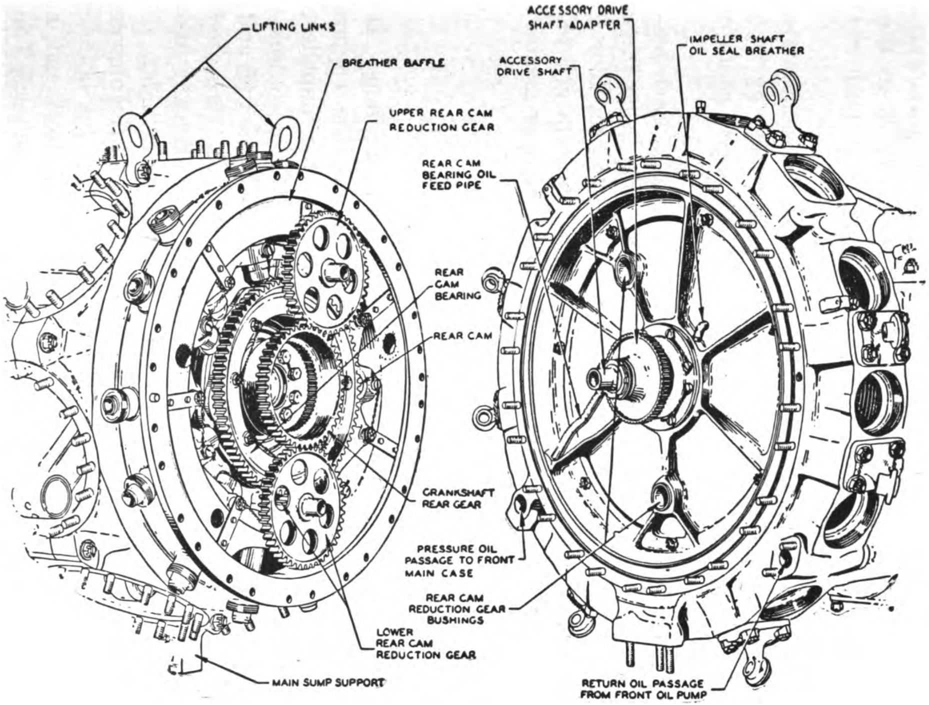


Figure 45.—Rear cam compartment and blower section.

A valve-clearance adjusting screw and locknut are incorporated in each rocker. The adjusting screw has a steel insert which acts as a contact between the screw and the valve stem, and minimizes friction at this point.

Valve tappets actuate the rockers through tubular push rods. These rods have ball ends which mate with sockets in the tappets and rockers. The push rods are enclosed in push-rod housings.

A rocker box cover is secured to each box. Two concentric valve springs are held in place on each valve stem by two washers and a split cone. The hollow exhaust valves contain sodium, which aids in cooling.

The full-skirted PISTONS are of aluminum alloy. Each piston has five ring grooves, and is fitted with compression rings in the first three grooves, dual oil control rings in the fourth groove, and an oil scraper ring in the fifth or bottom groove. Steel piston pins link the pistons to the articulated, or master, rods.

BLOWER SECTION

The BLOWER CASE supports the engine in the airplane. It has eight pads on the outer circumference for the engine mounting brackets. The blower case houses the impeller, which is driven by clutches at either 7.15 or 8.47 times crankshaft speed. An annulus around the case delivers the fuel and air mixture from the impeller to 14 ports in the case. Attached to each of these ports is an intake pipe through which the fuel and air mixture proceeds to the inlet valve of its cylinder.

The ACCESSORY DRIVE SHAFT extends through both the blower and the intermediate rear sections, passing inside the hollow impeller shaft, as may be seen in figure 46. The front end is coupled to the crankshaft rear gear by a splined adapter. The rear end of the shaft is splined into the plates of the accessory spring drive gear. This gear drives the clutches and the generator intermediate drive gear.

The IMPELLER is splined and shrunk to the impeller shaft in a semipermanent assembly. The impeller shaft is hollow and is supported internally on the accessory drive shaft by two

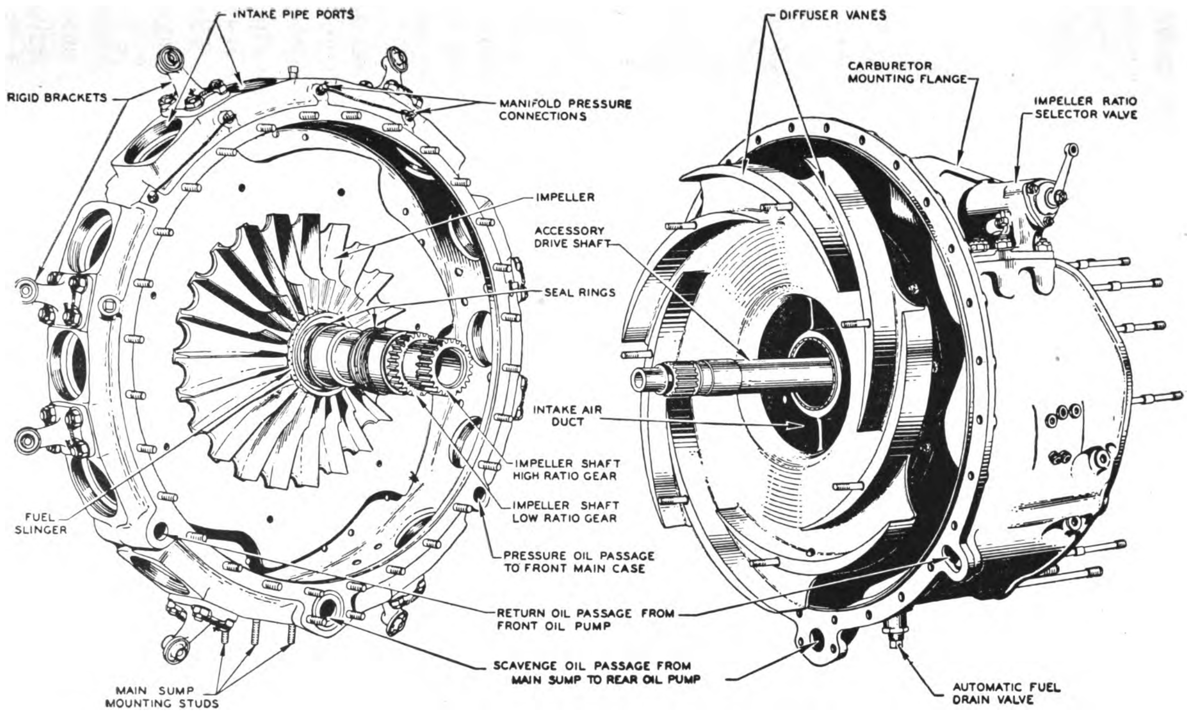


Figure 46.—Blower and intermediate rear sections.

journal bearings. The oil seal rings in the impeller shaft front carrier are seated in the blower case liner. The rings on the rear carrier are seated in a liner in the intermediate rear case. Two spur gears, integral with the rear of the impeller shaft, mesh with and are driven by the high-ratio and low-ratio clutch gears, as illustrated in figure 47.

INTERMEDIATE REAR SECTION

The INTERMEDIATE REAR CASE houses the impeller drive gear train and supports a vaned diffuser. The impeller ratio selector valve is mounted on a pad on the top left of the case. From the carburetor mounting flange on the top of the case, a large duct leads down to carry the intake air to the impeller.

The fuel transfer pipe from the carburetor connects with a passage in the case behind the carburetor mounting flange. This passage leads to the fuel feed valve. The fuel feed valve delivers fuel to the fuel slinger which mixes the fuel with the intake air.

The cover and diaphragm assembly of the fuel feed valve are mounted on the forward side of the carburetor flange. Behind the accelerating pump pad is the magneto vent connection. At the lowest point in the carburetor air duct, passages lead down to the automatic fuel drain valve in the bottom of the case. This valve discharges any fuel that may be accumulated while the engine is being started.

DUAL RATIO CLUTCHES and an IMPELLER RATIO SELECTOR VALVE provide for a high and low ratio. Both a high (8.47:1) and a low (7.15:1) ratio clutch are mounted on each of two shafts, one on each side of the impeller shaft. These shafts are supported at the front end by bushings in the intermediate rear case, and at the rear end by bushings in the rear case. The shafts are driven by the accessory spring drive gear through pinions splined to the shafts.

The clutch cones are splined to the clutch shafts. When engaged, they drive the clutch gears. These gears, in turn, drive the spur gears in the impeller shaft. The selector valve directs pressure oil to oil chambers between the cones and the gears of either the low-ratio or the high-ratio clutches. Drain

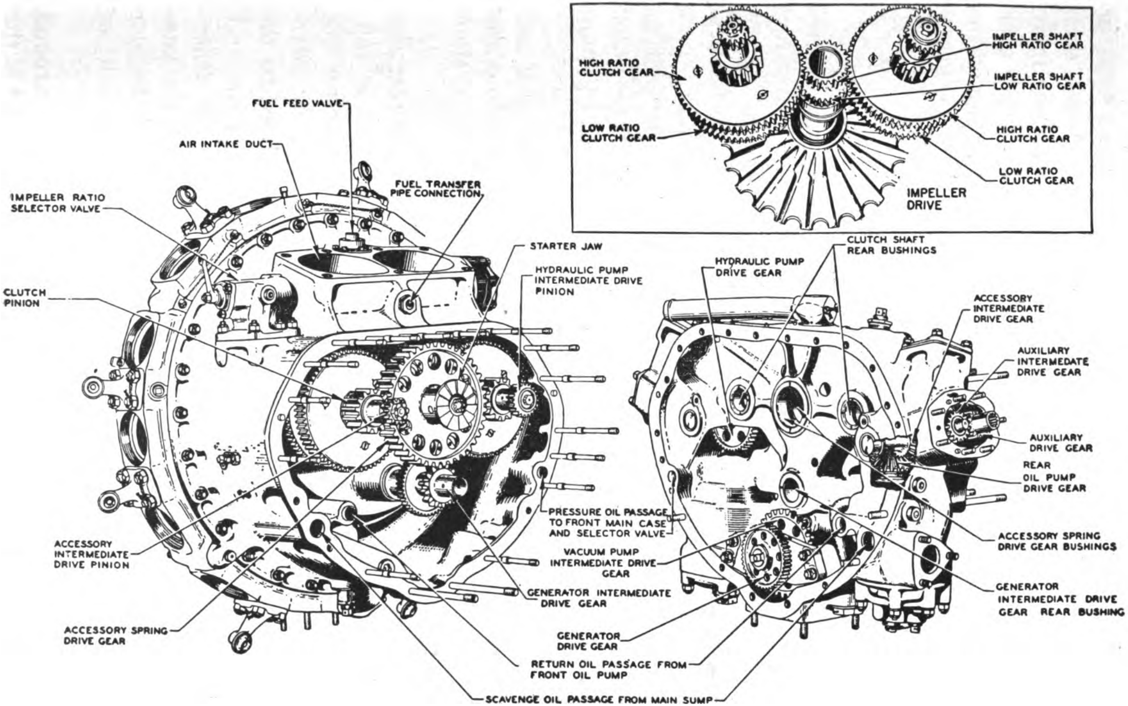


Figure 47.—Intermediate rear and rear sections.

oil is forced back through the selector valve and discharged into the intermediate rear case.

Some engines incorporate the creeper desludging type of clutch. To assist in cleaning sludge from the clutches, each clutch gear is equipped with a creeper gear having one more tooth than the clutch gear. A bleed hole in the creeper gear aligns momentarily with each of the bleed holes in the corresponding clutch gear. The pressure oil within the engaged clutch shoots out, carrying the sludge with it.

REAR SECTION

The REAR CASE houses and supports accessory drives and adapters. It has mounting pads for the starter, generator, tachometer, and vacuum pump, and carries adapters for the hydraulic pump, fuel pump, and two auxiliary accessories. Figure 48 shows the rear view of the accessory section.

The oil pressure relief valve is located in the rear face of the case between the fuel pump adapter and the generator mounting pad. The oil outlet pad is just below the fuel pump adapter.

Near the bottom (on the left side) is the oil inlet pad, and on the right side is the bypass valve. The rear oil pump and the main oil screen are installed in the bottom left and right sides of the case, respectively.

The ACCESSORY SPRING DRIVE GEAR is splined to the rear end of the accessory drive shaft through its plates, and is supported in bushings in the rear case. This gear drives the clutch shaft pinions on either sides, and the generator intermediate drive gear below. The starter jaw is splined to the hub of the rear plate of the accessory spring drive gear.

The GENERATOR INTERMEDIATE DRIVE GEAR drives the generator gear directly beneath it. This gear also drives the vacuum pump intermediate drive gear. The generator drive gear is splined to a shaft which is supported between the walls of the rear case by bushings in the walls.

The vacuum pump intermediate drive gear rotates around the generator drive gear shaft on a bearing incorporated in the gear, and drives the vacuum pump drive gear. The latter is supported vertically beneath the generator drive gear shaft

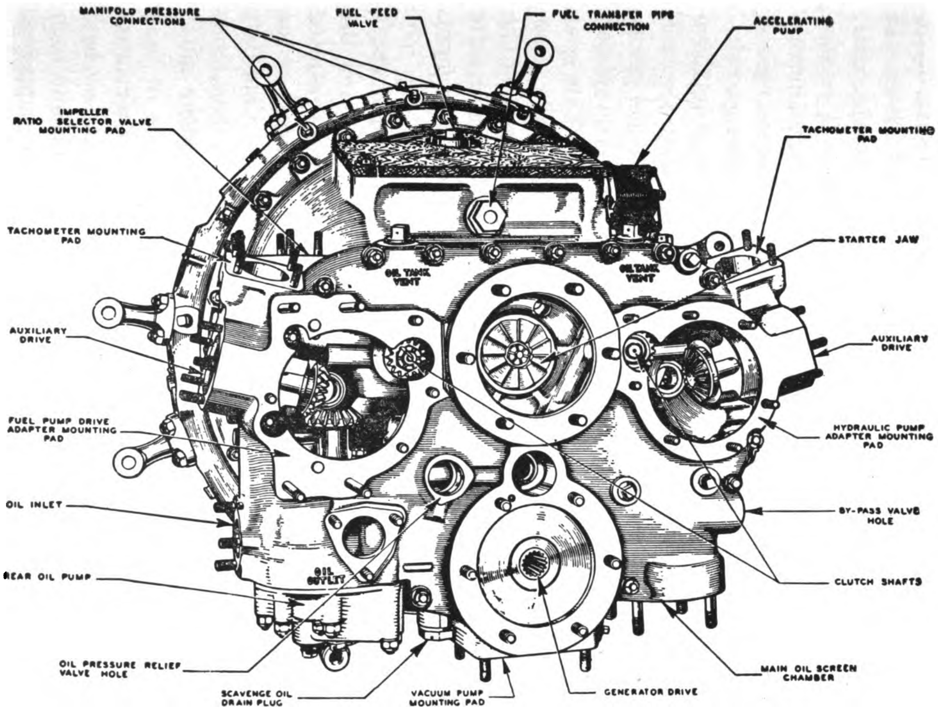


Figure 48.—Rear view of accessory section.

by a bushing in the vacuum pump drive gear housing. Splines are provided in the outer ends of the generator drive gear shaft and the vacuum pump drive gear for driving the generator and the vacuum pump.

The ACCESSORY INTERMEDIATE DRIVE GEAR is driven by a pinion splined to the rear end of the left clutch shaft. It drives the rear oil pump drive gear, the fuel pump drive gear, and the left tachometer intermediate drive gear. It is supported at the front end by a bushing in the fuel pump adapter.

The REAR OIL PUMP DRIVE GEAR SHAFT carries three spur gears. These gears are secured by keys, and mesh with idler gears inside the three sections of the pump body. The fuel pump drive is housed in the fuel pump adapter attached to the rear case. The drive has splines at the outer end for driving a fuel pump.

The HYDRAULIC PUMP DRIVE GEAR is driven by a pinion splined to the rear end of the right clutch shaft. This gear drives the right-hand tachometer intermediate drive gear. The front end is supported by a bushing in the rear case. The rear end, which has internal splines for driving the hydraulic pump, is supported in two bushings in the hydraulic pump adapter attached to the rear case.

The left and right TACHOMETER INTERMEDIATE DRIVE GEARS are driven by the accessory intermediate drive gear and the hydraulic pump drive gear, respectively. They are mounted in housings in the sides of the rear case and supported at the outer ends by bushings in the auxiliary adapters. The left and right tachometer drive gears are supported at both ends in the walls of the rear case, and are driven by their intermediate drive gears.

Pinions splined to the outer ends of the tachometer intermediate drive gears drive the AUXILIARY DRIVE GEARS on both sides of the engine. These gears have internal splines in their outer ends for driving additional accessories, and are supported in the tachometer intermediate drive gear housings and the auxiliary adapters.

ENGINE LUBRICATION SYSTEM

Oil is circulated through the engine by the REAR OIL PUMP. Oil from the tank enters the engine through the inlet port and

descends to the bottom stage of the three-stage pump. Oil is forced from the pump through a passage in the rear case, through the screens in the strainer, and upward to the spring-loaded check valve in the top of the screen assembly.

When the engine is not running, the check valve prevents oil in the tank from entering the lubrication system of the engine. If the screens become clogged or the check valve sticks, the bypass valve allows the pressure oil to pass through the engine. When the oil emerges from the check valve in the main oil screen chamber, it enters the two main branches of the lubrication system.

In the FIRST BRANCH of the lubrication system, oil from the oil screen chamber is directed through a passage to an annular groove which encircles the rear bushing of the generator intermediate drive gear. Part of the oil passes through metering holes in the generator intermediate drive gear bushing and shaft. These holes reduce the pressure of the oil which enters the hollow shaft.

From the interior of the shaft, this low-pressure oil goes through a series of connecting channels to lubricate the gears and bushings in the intermediate rear and the rear sections.

Oil from the annular groove is also directed under pressure into two other principal channels. One of these channels conducts pressure oil to the oil pressure relief valve. This valve is adjusted to maintain an engine oil pressure of from 85 p.s.i. to 100 p.s.i. Oil bypassed through the relief valve returns to an opening behind the oil inlet port.

The other principal oil channel conducts pressure oil upward to an annular groove between the two bushings of the accessory spring drive gear. From this point, a drilled passage runs to a connection in the upper right corner of the rear case where the pressure oil may be utilized as a source of external supply. From the annular groove, oil enters the accessory drive shaft through drilled holes, and flows forward inside this shaft into the rear end of the crankshaft.

Drilled passages in the crankshaft carry the oil through the two crankpins to the master rod bearings. Holes in these bearings convey pressure oil to annular distributing grooves in the master rod bores. These grooves distribute the oil through

drilled passages in the master rod and knuckle pins to the knuckle pin bushings.

The crankshaft bearings, cylinder walls, and piston pins are lubricated by spray oil thrown from the master rod bearings and knuckle pin bushings. Additional lubrication is furnished to the moving parts within the crankcase section by oil discharged from two jets in the crankshaft.

Pressure oil from the front end of the crankshaft passes through a pipe into the interior of the propeller shaft. Oil from this shaft proceeds outward through the reduction gear pinion shafts to the pinion bearings.

The teeth of the reduction gears have two sources of lubrication—oil thrown from the pinion bearings and from three jets in the propeller shaft. The internal pipe in the propeller shaft carries oil forward to the propeller mechanism.

In the SECOND BRANCH of the lubrication system, pressure oil flows forward from the chamber above the main oil screen assembly through passages in the right side of the rear and intermediate rear cases. These passages supply pressure oil to three principal channels—A, C, and D.

OIL CHANNEL A carries oil to the front cam compartment and to the front section. A transfer pipe in the right-hand wall of the blower case connects with an external pipe which carries oil to the bottom of the front crankcase.

An oil transfer pipe in the front crankcase carries this oil to the spark advance selector-valve body. The selector valve directs pressure oil through pipes either to the normal or to the cruising side of the spark advance piston, depending on the position of the valve plunger in its guide.

From the selector-valve body, a short pipe carries oil into the system of internal passages in the front crankcase. Oil from these passages lubricates the rear bushings of the front cam reduction gears. It then passes forward through the gear shafts to the front bushings, and continues through drilled passages in the support plate and the cam bearing support to an annular groove encircling the front cam bearing.

Oil from the drilled passages in the support plate also lubricates the magneto intermediate drive bushings and bearings. Other drilled passages lead oil from the internal passages into

each tappet guide boss, the tappet guides, and the tappets.

From the tappet guides, the oil goes through the hollow push rods to the rockers. A short pipe carries the oil forward from the spark advance selector-valve body to supply the propeller governor and to lubricate the governor drive gear bushing.

Oil from the governor is conveyed by another passage and pipe to the oil transfer bearing. From there it passes into the propeller shaft where it may be utilized to operate a hydraulic propeller. Some oil from the transfer bearing also reaches the thrust bearing in the front end of the front case.

Oil channel C provides lubrication for the impeller shaft thrust plates and the moving parts in the rear cam compartment. A small pipe carries oil from the transfer pipe in the right-hand wall of the blower case across the front face of the blower case to a bracket. From this bracket, a short pipe leads into the central boss of the case to bring oil to the thrust plates.

The bracket also transmits oil into an internal passage in the cam shelf in the rear section of the crankcase. Here, a drilled hole allows the oil to reach an annular groove on the rim of drilled passages in the tappet guide bosses.

The tappets, push rods, and rockers of the rear cylinders are lubricated in the same manner as those in the front row of cylinders. Auxiliary passages and the hollow shafts of the gears similarly provide oil to lubricate the front and rear bushings of the rear, cam-reduction gears.

Oil channel D is a drilled passage in the intermediate rear case which carries pressure oil to the impeller ratio-selector valve to operate the clutches.

In the scavenge system, drain oil from the rocker boxes collects in the rocker box sump on the No. 8 cylinder head. The oil reaches this sump through external pipes linking the rocker box covers of the lower cylinders. The sump is scavenged by one stage of the front oil pump through an external suction pipe attached to the front case.

Oil from the rocker boxes of the upper cylinders drains into the front and rear crankcase sections through the push rod covers and grooves in the tappet guides. The drain oil collecting in the bottom of the front case and the front cam com-

partment is scavenged by a second stage of the front oil pump.

Both stages of the pump force oil back through an external pipe extending from the bottom of the front case to the forward left side of the blower case. The return oil from this pipe proceeds through passages in the blower, intermediate rear, and rear cases, and reaches the oil outlet passage just forward of the oil outlet port.

Oil thrown off the moving parts in the crankcase sections and the rear cam compartment collects in the bottom of the rear section of the crankcase and drains through two pipes into the main sump between No. 7 and No. 9 cylinders. The oil in the main sump is then scavenged by the middle stage of the rear oil pump through a series of passages in the blower, intermediate rear, and rear cases, and is discharged through the outlet port.

The screen in the main sump catches foreign matter in the drain oil. Drain oil which collects in the bottom of the intermediate rear and rear cases is similarly scavenged by the top stage of the rear oil pump.

CARBURETOR

Model R–1830 engines are equipped with injection carburetors which meter fuel in proportion to the mass flow of air into the engine. The mass airflow into the engine is controlled by the throttle opening. The fuel, after being metered by the carburetor, is discharged at the blower throat. There it is taken up by the impeller, mixed with the air, vaporized, and then delivered to the cylinders through the intake and the inlet valves.

The automatic spark advance control unit is mounted on the carburetor and connected to the lines leading from the blower rim and blower throat to the operating unit on the front section of the crankcase.

IGNITION

Ignition for model R–1830 engines is provided by two MAGNETOS mounted on the front case. Each magneto fires one of the spark plugs in each cylinder. The right magneto fires the

front plugs and the left magneto the rear plugs of both rows of cylinders. A system of vent lines connecting the magnetos to the blower throat prevents the accumulation of moisture in the magnetos.

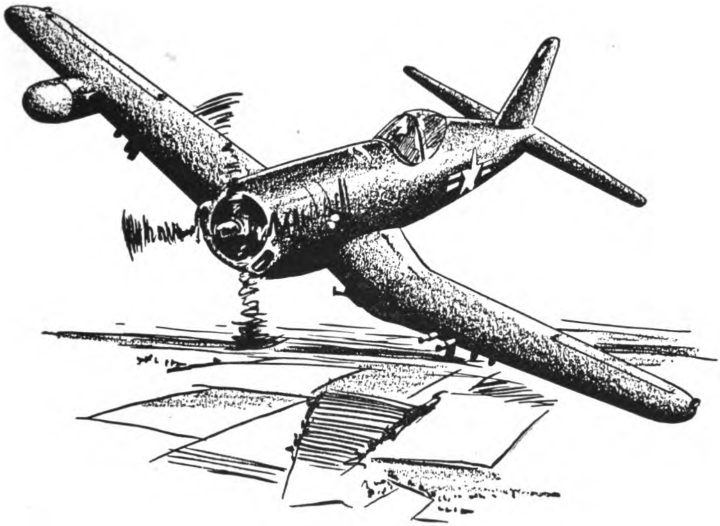
The IGNITION HARNESS is mounted around the front section of the crankcase and is fastened to the rear of the two magnetos. The manifold ring and the distributor block housings are filled with a plastic material for additional insulation and protection against moisture. The distributor blocks are sealed in the harness and should not be removed.

PROPELLER

Model R-1830 engines are equipped to mount constant-speed and full-feathering propellers of the hydraulically controlled type. The front case contains the oil passages for introducing the oil into the propeller shaft and thence into the propeller.

QUIZ

1. In the Pratt & Whitney Twin Wasp R-1830 engine, where are the magnetos mounted?
2. How are the magnetos timed?
3. How many sections are there in the crankcase?
4. In what cylinders are the master rods located?
5. How is the engine supported in the airplane?
6. What is the function of the automatic fuel drain valve?
7. What pump circulates oil through the engine?
8. What oil pressure is maintained in the engine?
9. How are the master rod bearings lubricated?
10. Where is the rocker box sump located?



CHAPTER 7

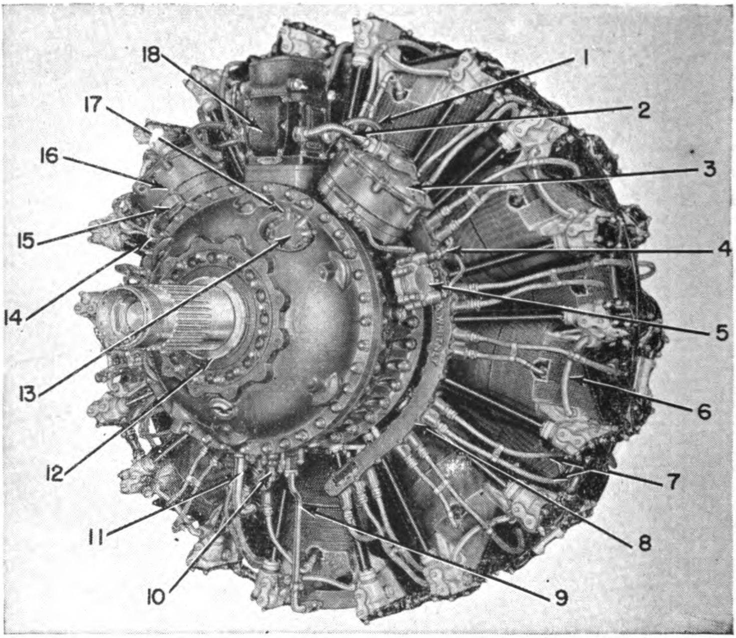
PRATT & WHITNEY DOUBLE WASP (R–2800) ENGINE

The model R–2800–22 engine (see figs. 49, 50, 51), manufactured by Pratt & Whitney, is the basic model of the Double Wasp, C Series powerplants. This plant is an 18-cylinder, twin-row radial, air-cooled engine having a total piston displacement of 2,804 cubic inches.

The general description of this engine is presented under the following headings: front section, front accessory section and front support plate, power section, supercharger section, lubrication system, ignition system, carburetor and fuel feed valve, combat power, and propellers.

FRONT SECTION

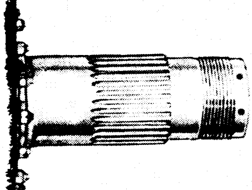
The FRONT CASE incorporates a recessed liner at its front end which supports the propeller shaft thrust bearing. This is a ball bearing which has a split inner face and supports the front



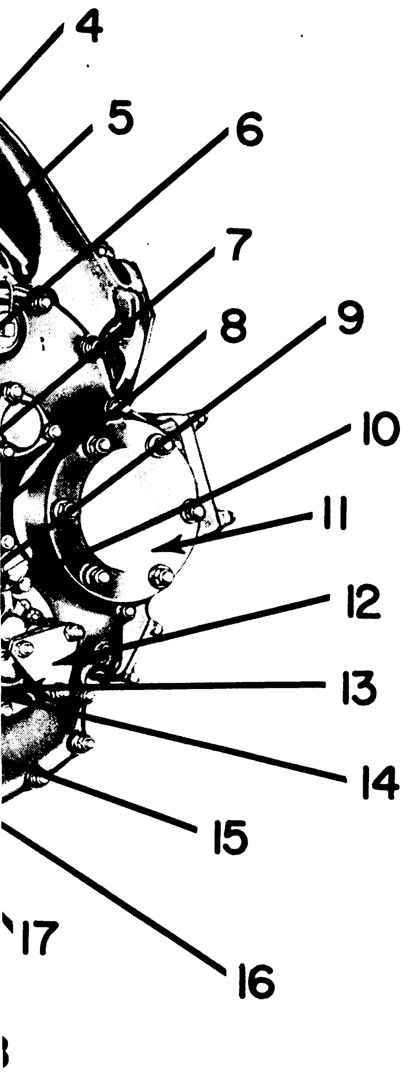
1. Magneto pressurizing line.
2. High tension lead.
3. Distributor housing cover.
4. Automatic spark advance tubing.
5. Automatic spark advance operating unit.
6. Inter-ear drain tube.
7. Spark plug leads.
8. Ignition manifold.
9. Rocker drain oil manifold suction tube.
10. Front oil scavenge and torquemeter booster pump.
11. Scavenge oil return tube.
12. Thrust bearing nut.
13. Torquemeter oil pressure transmitter.
14. Distributor air intake line.
15. Distributor air intake cover.
16. Distributor housing.
17. Torquemeter gage connection.
18. Magneto.

Figure 49.—Left front view of R–2800 engine.

end of the propeller shaft. A boss is incorporated in the front case for installation and support of the governor oil transfer pipe. A mounting pad is provided for a torque-indicator oil-



1. Magneto ground terminal.
2. High tension lead.
3. Magneto pressurizing line.
4. Governor oil transfer tube plug.
5. Governor mounting pad.
6. Front scavenge oil return duct and transfer tube.
7. Auxiliary supercharger inlet port.
8. Auxiliary supercharger control.
9. Main oil sump scavenge passage strainer plug.
10. Tachometer drive.
11. Side auxiliary mounting pad.
12. Breather.
13. Auxiliary supercharger outlet port.
14. Spark advance control unit.
15. Spark advance tubing.
16. Primer line tubing.
17. Front exhaust stack.



1. Automatic mixture control.
2. Fuel transfer tube.
3. Electric primer unit.
4. Hydraulic coupling selector valve.
5. Vacuum pump mounting pad.
6. Starter mounting pad.
7. Low pressure relief valve.
8. Oil pressure compensating relief valve.
9. Fuel pump mounting pad.
10. Oil temperature connection.
11. High speed generator mounting pad.
12. Oil outlet.
13. Main oil scavenge pump.
14. Main oil screen by-pass valve.
15. Oil inlet.
16. Oil pressure pump.
17. Rear section scavenge oil strainer drain plug.
18. Main oil screen drain plug.
19. Rear section drain plug.
20. Main oil sump drain plug.
21. Auxiliary supercharger intake port.
22. Tachometer drive.
23. Distributor air intake.
24. Auxiliary supercharger intake port.
25. Side auxiliary mounting pad.
26. Thermocouple leads.
27. Rear cam oil transfer tube.
28. Water control unit.
29. High pressure oil gage connection.
30. Engine mounting bracket boss.
31. Thermocouple adapter.
32. Manual mixture control.

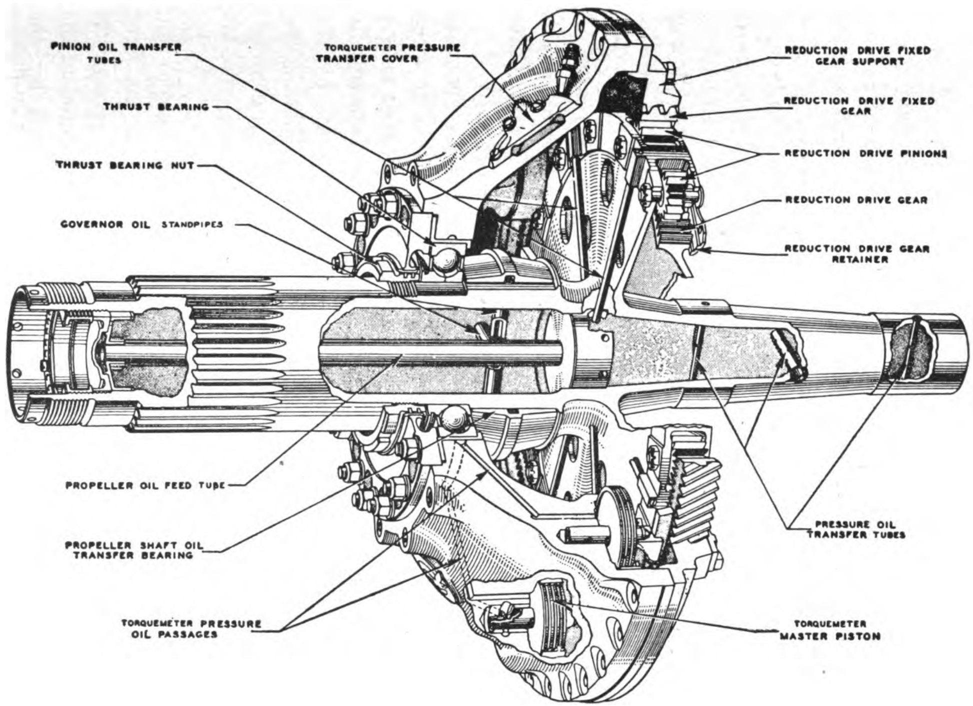


Figure 52.—Cutaway view of front section (20:9 reduction gearing).

pressure transfer cover. Six circular, steel-lined recesses are located in the rear of the front case to house six torque indicator pistons. A bracket secured to the rear side of the front part of the front case positions the propeller shaft oil transfer bearing.

The propeller reduction gear ratio is 20:9, and the reduction gearing is of the spur planetary type. The reduction drive fixed gear is an internal spur-ring gear with diagonal splines on its outside diameter. These splines mesh with splines machined in the reduction drive fixed gear support.

This support is secured to the rear face of the front case. Six reduction drive fixed gear retainers bolted to the support hold the gear in place. A coupling, splined to the front end of the crankshaft, mates with internal splines in the reduction drive gear and transmits power from the crankshaft to the drive gear. Teeth on the outside diameter of the drive gear mesh with 15 reduction drive pinions housed in the reduction drive pinion cage, which is integral with the propeller shaft. Each pinion is held in the cage by a pinion shaft and mates with the teeth on the outside diameter of the fixed gear.

The TORQUE INDICATING SYSTEM makes possible the accurate measurement of the actual power output to the propeller when the airplane is in flight. The reduction drive fixed gear moves forward on the diagonal splines on its outside diameter in response to the torque applied to the propeller shaft by the crankshaft through the reduction drive gear. As this occurs, the forward thrust of the reduction drive fixed gear is counterbalanced by pressure oil operating on the gear through the six torque-indicator pistons.

Each piston carries two oil seal rings, is fitted on its rear end with a slipper bearing which maintains contact with the fixed gear, and is retained in its recess by a cover. Oil pressure is supplied by the booster section of the oil pump mounted in the front accessory case. The pressure oil is received by the master piston located in the bottom of the front case.

This piston meters the flow of oil to itself and the five other pistons. Such metering is in direct proportion to the varying load applied to the six pistons through the reduction drive fixed gear. Thus, the reduction drive fixed gear is always

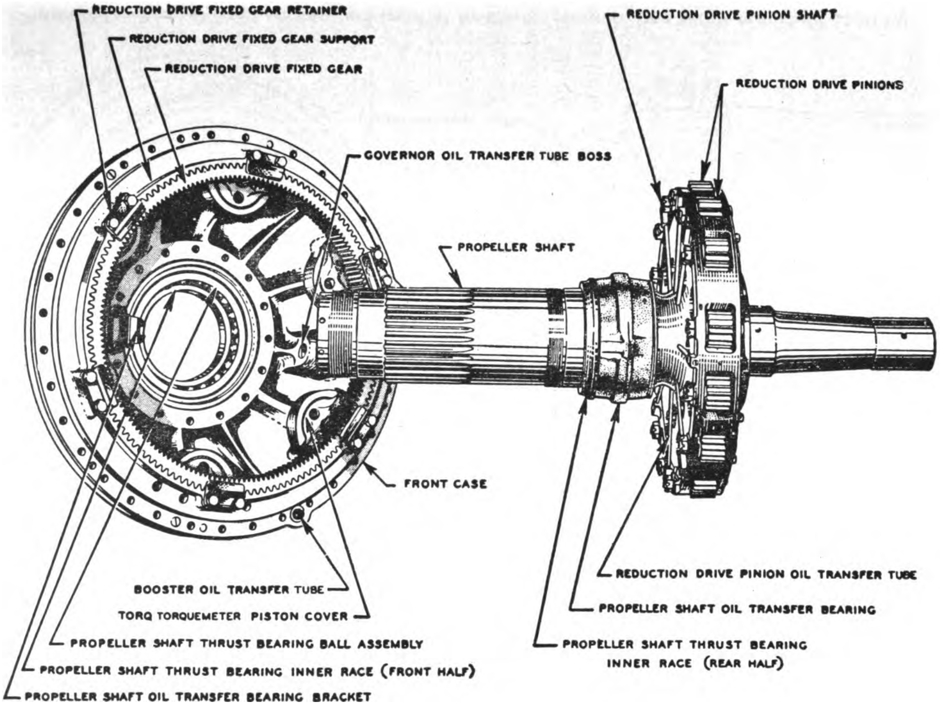


Figure 53.—Front case and reduction gear assembly (20:9 reduction gearing).

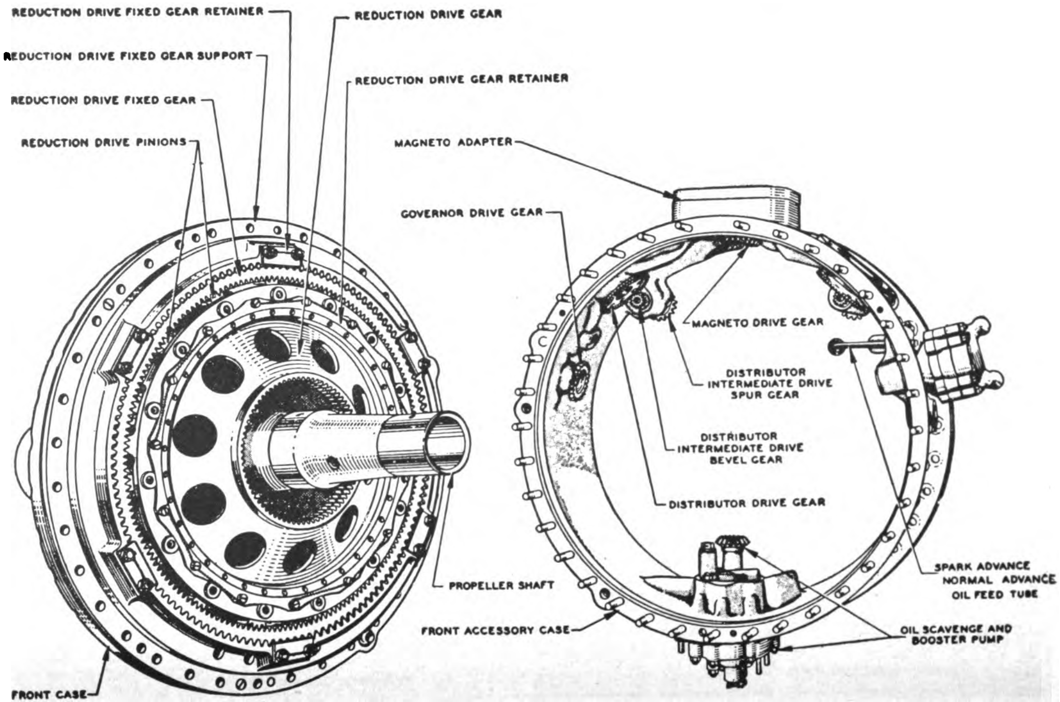


Figure 54.—Rear of front section and front of front accessory section (20:9 reduction gearing).

balanced by oil pressure acting against the front side of the pistons.

Oil pressure acting on the torque-indicator piston also acts, through a corded passage, on a pressure transfer diaphragm mounted on the front case. This diaphragm transmits the pressure through a pipeline filled with a low viscosity fluid to a pressure gage in the cockpit. By calculating the oil pressure acting on the torque-indicator pistons together with the engine r.p.m. and a previously determined torque constant, the pilot can determine the horsepower being delivered to the propeller.

FRONT ACCESSORY SECTION AND FRONT SUPPORT PLATE

External pads on the FRONT ACCESSORY CASE provide mountings for a dual magneto, twin distributors, an automatic spark advance operating unit, a propeller governor, and the oil scavenge and booster pump. On its inside surface, the front accessory case supports the two distributor drive gears and the distributor intermediate drive spur and bevel gears.

The FRONT SUPPORT PLATE is secured to the main crankcase section. Units supported by this plate are the intermediate gears for driving the front accessories, the front cam, and the front secondary counterbalance. The front support plate also houses the spark advance piston.

The SCINTILLA MAGNETO is driven through a train of gears. This train of gears starts with the crankshaft front gear and runs through the spark advance gear system and the magneto intermediate drive gears (which are mounted on the front support plate), to the magneto drive gear mounted in an adapter on the front accessory case.

Each G.E. MAGNETO is driven by a train of gears that starts with the crankcase front gear and runs through the spark advance gear system and the respective distributor drive idler gear (both of which are mounted on the front support plate), and then through the distributor intermediate drive gears (on the side of the front accessory case), to the distributor drive gear (mounted in the front accessory case).

Each DISTRIBUTOR is driven through a train of gears which starts with the crankshaft front gear and runs through the

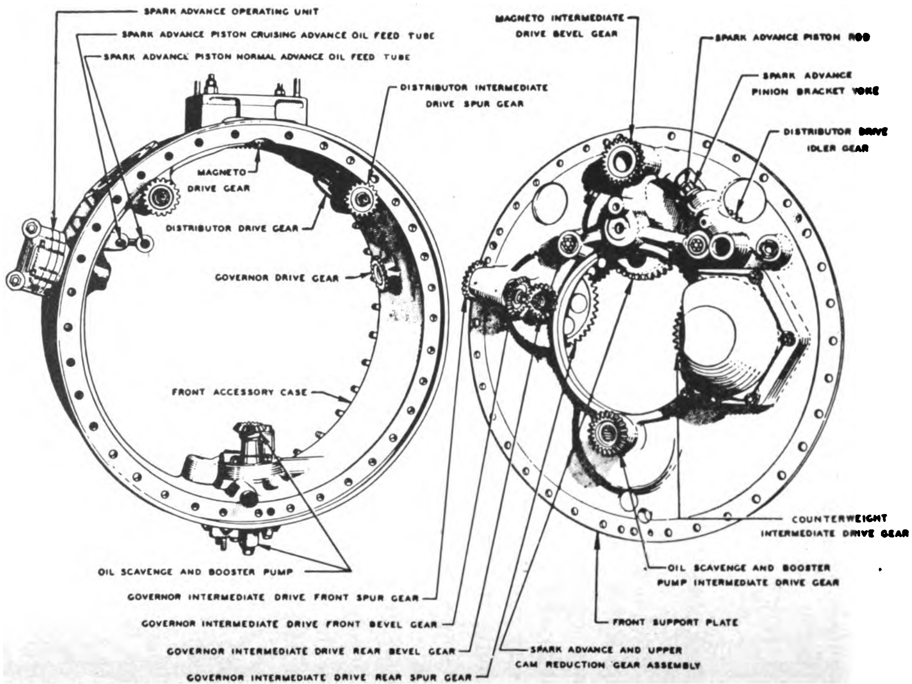


Figure 55.—Rear of front accessory section and front of front support plate.

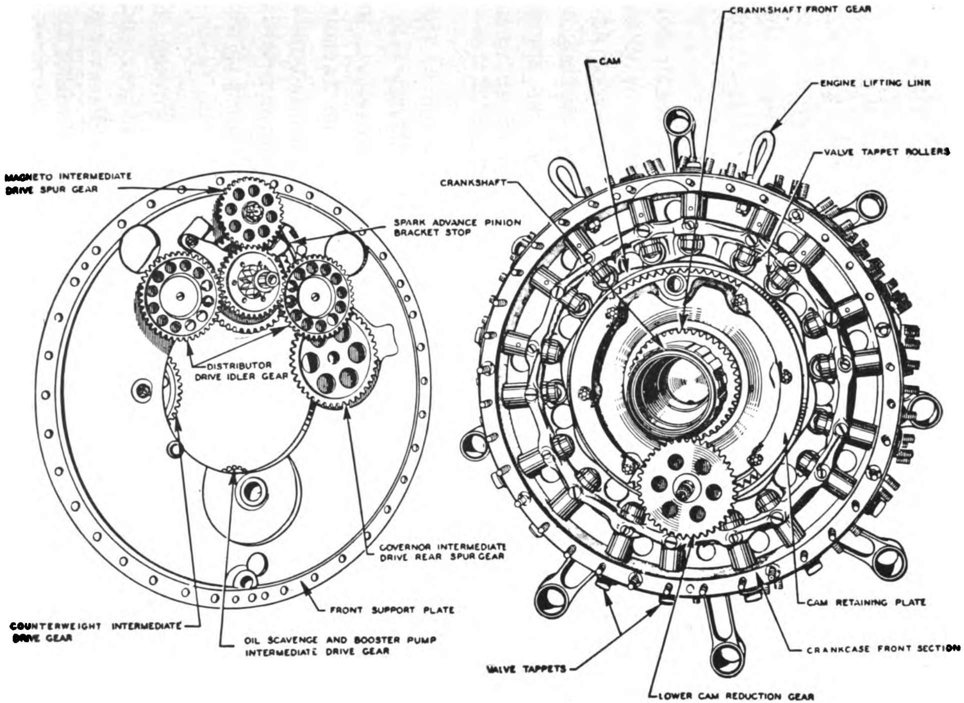


Figure 56.—Rear of front support plate and front of crankcase section.

spark advance gear system and the respective distributor drive idler gear (both of which are mounted on the front support plate). From here, the train of gears runs through the distributor intermediate drive gears on the side of the front accessory case, to the distributor drive gear mounted in the front accessory case.

The SPARK ADVANCE OPERATING UNIT is mounted on the front accessory case and is connected by a system of tubing to the blower rim, blower throat, and to the spark advance control unit on the carburetor. Pressure differential between the blower rim and throat acts through the tubing on a diaphragm in the operating unit.

The diaphragm, in turn, actuates the operating unit selector valve. Movement of this selector valve allows pressure oil to be directed to either the cruising advance or the normal advance side of the spark advance piston. This piston is mounted in the front support plate, and acts on the spark advance gear system through a yoke on the spark advance pinion bracket.

As the position of the piston changes, the position of the spark advance pinions alter with respect to their driving gear. Since the position of their driving gear is fixed with respect to the crankshaft, the change of position of the piston (acting through the pinions, the pinion-driven gears, and the magneto and distributor intermediate drive gears), advances or retards the timing of the magneto and distributors with respect to the crankshaft.

The OIL SCAVENGE AND BOOSTER PUMP is driven through a train of gears which starts with the crankshaft front gear and runs through the lower cam reduction gear and the oil scavenge and booster pump intermediate drive gear (both of which are mounted on the front support plate), to the drive gear in the pump. This drive gear is mounted in the front accessory case.

The GOVERNOR is driven through a train of gears which starts with the crankshaft front gear and runs through four intermediate gears on the front support plate to the governor drive gear, which is mounted in the front accessory case.

The three sections of the crankcase are held together by studs and special bolts. Two rows of cylinder mounting pads are located around the outer circumference of the crankcase assembly. Steel-backed, prefitted bearings with leaded bearing surfaces are shrunk into the bore of the front and rear sections of the crankcase to support the front and rear sections of the crankshaft.

The center section of the crankshaft is supported by a two-piece bearing of the same type. This bearing is seated in a liner shrunk into the center section of the crankcase and held in position by retaining plates. Rotation of the front and rear main bearings is prevented by four lock-tabs on the flanged end of each bearing.

The cams and cam bearings are supported on integral, circular bosses on the front and rear sections of the crankcase.

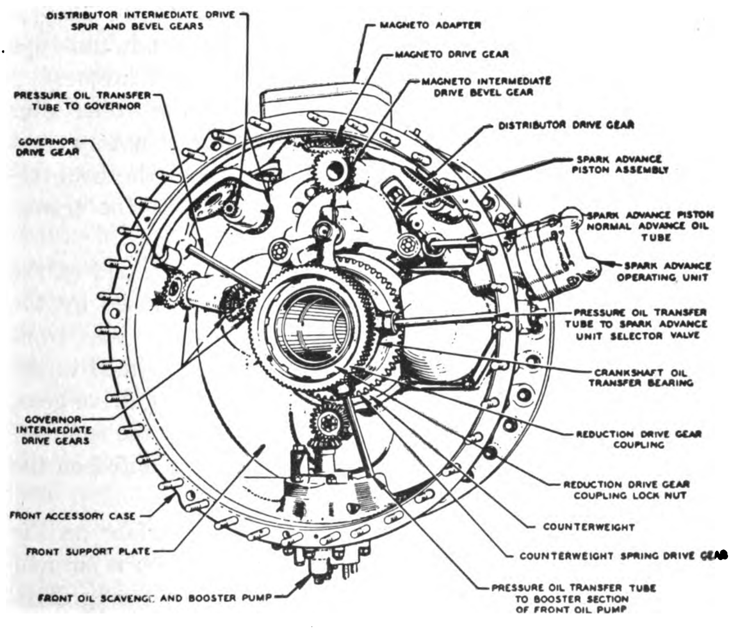


Figure 57.—Front support plate and front accessory section assembled to crankcase section.

The rear ends of the front cam reduction gears and the front ends of the rear cam reduction gears are supported in the front and rear sections of the crankcase, respectively.

The valve tappet guides and tappets for the front and rear rows of cylinders are supported in the corresponding section of the crankcase. Four engine lifting links are secured to the crankcase, two in the front section and two in the rear section.

The REAR SUPPORT PLATE is secured to the rear section of the crankcase, and supports the rear end of the rear cam reduction gears and the front end of the rear counterbalance intermediate drive gear shaft.

The CRANKSHAFT is machined from three steel forgings. The front and rear sections are held to the center section by bolts which pass through the crankpins. The end of each crankpin and its mating face on the crankshaft center section are serrated. Each crankpin has a special sludge retainer on its inside diameter.

The crankshaft assembly is supported by the bearings in the main crankcase sections. The crankshaft cheeks are integral with the front and rear sections and support pendulum-type counterweights designed to dampen crankshaft vibrations.

Each counterweight is supported on two large roller pins which pass through steel-bushed holes in the counterweight and crankshaft cheek. The pendulum travel of the counterweights is controlled by stops which are bolted to the crankshaft cheeks.

A secondary counterbalance is provided at each end of the crankshaft to dampen second-order vibrations caused by the eccentric masses of the master rod assemblies. The front counterbalance turns on a leaded sleeve bearing splined to the front crankshaft section. A counterbalance spring drive gear, splined to the reduction drive gear coupling, drives the counterbalance intermediate drive gear. This gear is mounted on the front support plate.

The rear counterbalance turns on a leaded surface on the outside diameter of the crankshaft rear gear, which is secured to the end of the crankshaft. A counterbalance spring drive gear is splined to an adapter secured to the end of the crankshaft, and drives the counterbalance intermediate drive gear

mounted on the rear support plate. Each counterbalance intermediate drive gear drives its counterbalance at twice crankshaft speed.

The hollow front section of the crankshaft contains two steel-backed bronze bearings which support the rear of the propeller shaft. The reduction drive gear coupling and the crankshaft front gear are splined to the front end of the crankshaft. The reduction drive gear coupling supports the crankshaft oil transfer bearing and the front counterbalance spring drive gear. The rear end of the crankshaft has internal splines to accommodate the accessory drive shaft adapter.

The one-piece MASTER RODS are located in cylinders No. 8 and No. 9. The master rod bearings are one-piece steel shells having a special leaded surface. Each bearing is held in place by two retainer plates which fit on the faces of the master rod. The retainer plates have fingers which fit over bosses at each end of the full-floating, silver-plated knuckle pins. Eight I-section articulated rods are attached to each master rod by knuckle pins, and a piston is attached to each master and articulated rod by a piston pin.

As shown in figure 58, the double-track, four-lobe CAMS which actuate the valves in each row of cylinders, rotate on bronze bearings with leaded surfaces. They are mounted on the front and rear sections of the crankcase. The front cam is driven through a train of gears which starts with the front crankshaft gear and runs through two cam reduction gears and pinions. These latter units are supported by the front support plate and front section of the crankcase. The rear cam is driven through a similar train of gears. Both cams are driven opposite to crankshaft rotation at one-eighth crankshaft speed.

The TAPPET GUIDES are shrunk onto the front and rear sections of the crankcase. The outer ends of the tappet guides are supported in the crankcase wall, and the inner ends are anchored in bosses forged integral with the crankcase sections. Steel valve tappets with roller-type cam followers are mounted in the tappet guides. These tappets actuate the valve-operating mechanism in the cylinder heads through tubular pushrods which have ball ends.

The CYLINDER BARRELS are machined from steel forgings.

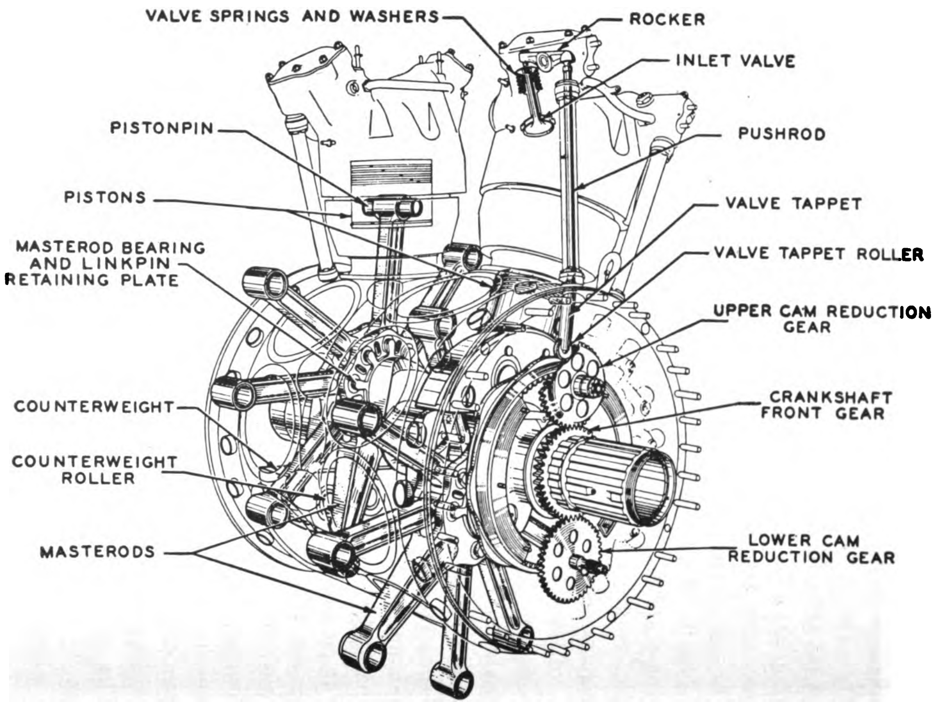


Figure 58.—Phantom view of power section showing vaive-operating mechanism.

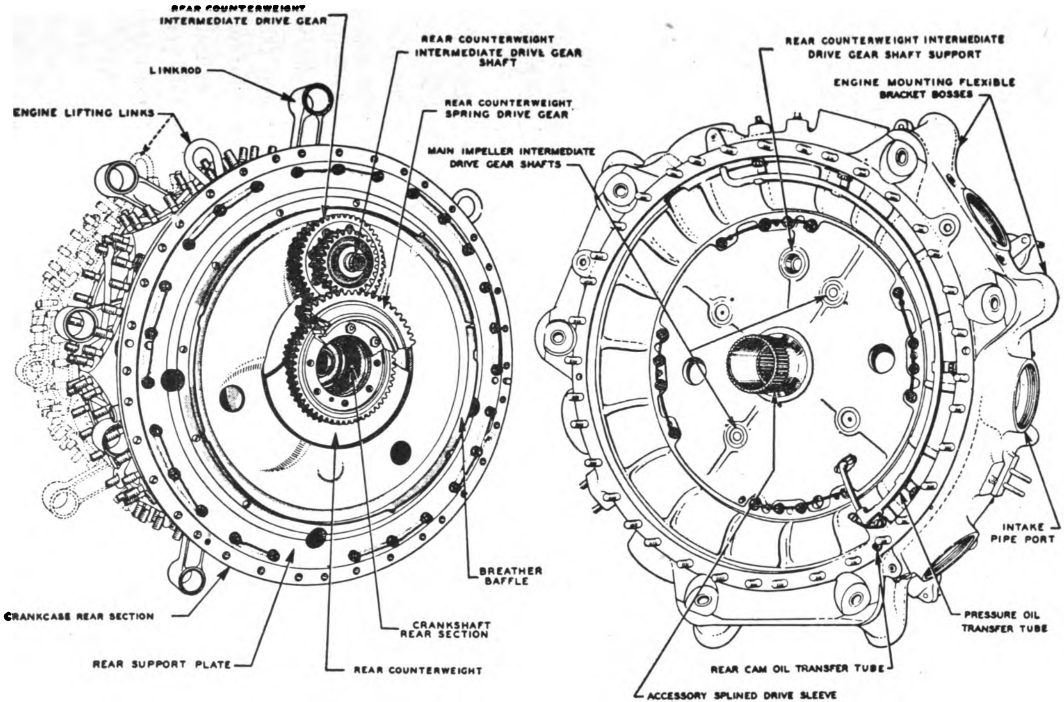


Figure 59.—Rear of crankcase rear section with rear support plate and front of main supercharger section.

Aluminum sleeves, in which cooling fins have been machined, are shrunk over the central portion of each barrel. The heads are of forged aluminum with machined cooling fins and integral valve rocker boxes. The cylinder heads are screwed and shrunk onto the barrels. Each cylinder has one inlet and one exhaust valve seat shrunk onto the cylinder head.

The cylinder head also incorporates bronze inlet and exhaust valve guides, heli-coil inserts for two spark plugs, and two steel bushings to support each rocker shaft. The cylinder barrels are provided with mounting flanges and are secured by studs and nuts to the crankcase.

The aluminum PISTONS are of the full-skirt type. Each piston has five ring grooves. Compression rings are fitted into the first three grooves, dual oil control rings in the fourth groove, and a rectangular-sectioned compression ring in the fifth groove. The top compression ring is chromium plated on the side which bears against the cylinder wall.

CYLINDER DEFLECTORS, located between the rocker boxes on each cylinder head and between adjacent cylinders, baffle a high-velocity flow of cooling air between and around cylinder fins.

All VALVE-OPERATING PARTS are enclosed. The rockers are supported on shafts which are, in turn, supported by bushings in the rocker boxes. The rocker arms are actuated by push rods with ball ends. These, in turn, are actuated by the cams and tappets in the front and rear main crankcase sections. The rockers are equipped with valve clearance adjusting screws and locknuts. The exhaust valves are hollow and are partially filled with sodium for cooling. Inlet valves are solid and have stems of smaller diameter than the stems of exhaust valves. Both inlet and exhaust valves are fitted with two concentric coil springs. These springs are secured to the valve stems by washers and split-cone locks.

MAIN SUPERCHARGER SECTION

The MAIN SUPERCHARGER CASE is attached to the crankcase rear section (fig. 59). This section supports the engine in the airplane through six integral, angular bosses which incorporate

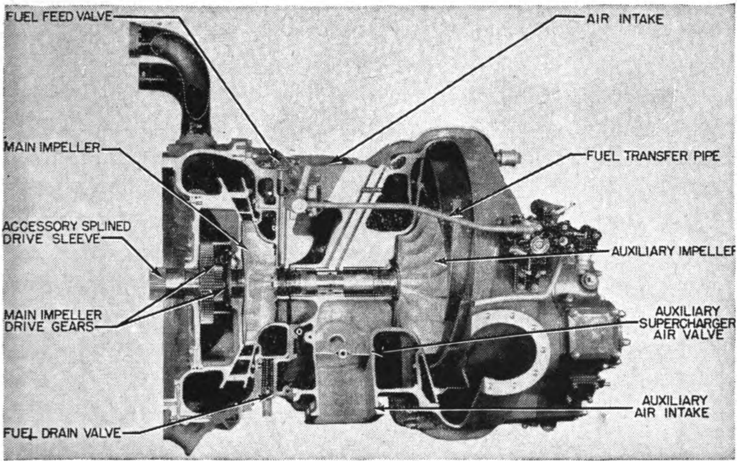


Figure 60.—Cutaway view of main supercharger inlet and auxiliary supercharger sections.

steel liners to accommodate the engine mounting flexible bracket assemblies. Nine outlet ports are located around the periphery of the case, and Y-shaped cylinder intake pipes are attached to these ports. A bowl-shaped center section divides the interior of the case, forming an annulus inside the outlet ports and a recess which houses the main impeller drive gear train at the front of the case. Bushings in the front face of the center wall support the shafts for the main impeller intermediate spring drive gears, and a steel liner in the center accommodates the four main impeller front oil seal rings and the thrust plate. The main impeller diffuser is supported on studs from the rear face of the center wall. Check figure 60 for a cutaway view of the main and auxiliary supercharger sections.

The MAIN IMPELLER ASSEMBLY is housed between the main supercharger and the supercharger inlet case. The main impeller shaft is hollow, with two bronze bearings pinned in the inside diameter. These bearings support the main impeller shaft on the accessory drive shaft. The impeller shaft incorporates splines for the main impeller and the impeller drive gear, as well as lands for the four front oil seal rings. The main impeller drive gear is locked onto the front splines, and

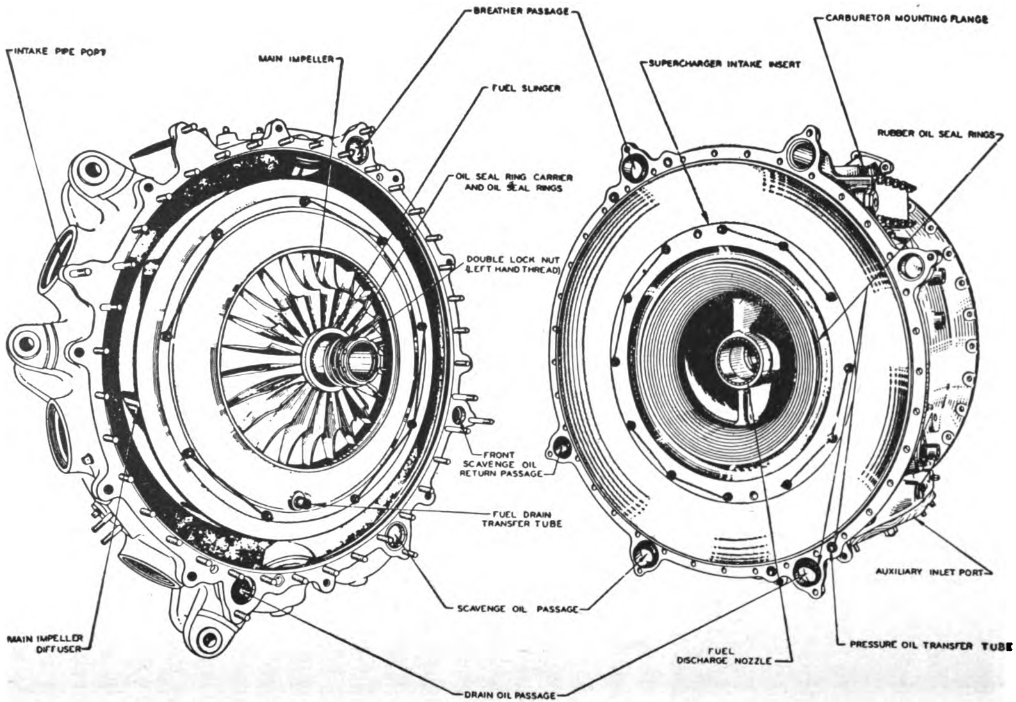


Figure 61.—Rear of main supercharger and front of supercharger inlet rear section.

the main impeller, fuel slinger, rear oil seal ring carrier, and two locknuts are installed on the rear of the shaft. Power is supplied from the crank-shaft to the main impeller shaft gear through the accessory splined drive sleeve, the main impeller spring drive gear, and the two main impeller intermediate spring drive gears.

The SUPERCHARGER INLET CASE attaches to the studs at the rear of the main supercharger case and incorporates inlet passages for both the main and auxiliary impellers (fig. 61). One inlet passage, incorporating a rectangular mounting flange for the carburetor, conducts air to the front of the case for the main impeller, while two smaller passages with rectangular parts conduct the air to the rear of the case for the auxiliary impeller.

Two gate valves on a single shaft, one in each auxiliary inlet passage, control the amount of air to the auxiliary impeller so that a constant pressure exists at the carburetor entrance.

The AUXILIARY SUPERCHARGER CASE attaches to the rear of the supercharger inlet case. A mounting pad for the water control unit of the combat power system is provided on the left side of the case, and the main breather outlet is located at the top right side.

The AUXILIARY IMPELLER ASSEMBLY is housed between the supercharger inlet and auxiliary supercharger cases. The auxiliary impeller shaft is hollow steel. Two bronze bearings, pinned in the inside diameter, support the assembly on the accessory drive shaft. The impeller drive gear is splined to the outside diameter of the shaft, and lands are machined on the shaft for the four rear oil seal rings. The auxiliary impeller drive gear is locked on the rear of the shaft, and the auxiliary impeller and front oil seal ring carrier are installed on the front of the shaft with a locknut.

High- and low-ratio HYDRAULIC COUPLINGS (see fig. 62) are mounted on each of the two shafts which are supported on either side of the impeller shaft between the rear and auxiliary supercharger cases. The two coupling shafts are driven by the accessory drive gear through a pinion splined on the rear of each shaft. The impellers of each coupling are splined to the shaft, and the runners, or driven impellers, are splined to the

respective coupling gears which are free running on the coupling shaft and mesh with the auxiliary impeller shaft gear.

When oil is directed into the high- or low-ratio couplings by the selector valve, the selected couplings fill with oil. Power is transmitted from the impeller to the runner, causing the coupling gear, which drives the auxiliary impeller shaft gear, to accelerate as the coupling fills until the coupling gear travels at the same r.p.m. as the coupling shaft.

In shifting from the high-ratio to the low-ratio coupling, a circular sleeve valve, located on the hydraulic coupling shaft between the low-ratio runner and impeller, prevents the low-ratio coupling from filling with oil until the auxiliary impeller has slowed to a point at which the low-ratio runner is traveling at a slightly lower r.p.m. than the low-ratio impeller. The low-ratio coupling valve will rotate on the coupling shaft when the r.p.m. of the low-ratio impeller equals or exceeds the r.p.m. of the low-ratio runner. The distance that the valve can rotate is controlled by a stop. When the valve rotates to the stop, the oil holes in the valve will line up with the oil holes in the shaft, allowing pressure oil from the shaft to enter the low-ratio coupling. When the shift is made from low to high, the r.p.m. of the low-ratio runner will exceed that of the impeller, which will cause the valve to rotate to the stop in the opposite direction. With the valve in this position, oil from the shaft will be blocked off and prevented from entering the low-ratio coupling.

The ACCESSORY DRIVE SHAFT is splined at the front end to an adapter which, in turn, is splined to the rear end of the crankshaft. The rear end of the shaft is splined to, and supported by, the hub of the accessory spring drive gear. This gear is supported in steel-backed bronze bushings in the rear case. The starter jaw is splined in the rear end of the accessory spring drive gear hub.

LUBRICATION SYSTEM

Oil from the tank is circulated through the engine by a gear-type pressure pump located in the left face of the rear case (fig. 62). The oil pressure pump cover is provided with

mounting bosses for an inlet oil connection, a compensating relief valve, and an oil screen chamber bypass valve.

The pump sends high-pressure oil to the main oil screen chamber located in the lower central portion of the rear case. An oil screen chamber bypass valve permits oil to bypass the oil screen if the screen becomes clogged.

A check valve at the top of this chamber eliminates oil flow from the main tank into the engine when the engine is not in operation. The oil passes through this check valve at the top of the screen chamber to a smaller chamber directly above. From this chamber, a passage connects with an annulus around the end of the oil transfer shaft.

A passage from this annulus runs to the front face of the compensating relief valve. Oil from this passage also circulates over the thermostat which controls the compensating action of the relief valve. When the oil temperature rises to 40° C. (104° F.), the thermostat opens, allowing pressure oil to flow to the compensating relief valve piston. The relief valve then permits oil to bypass to the oil inlet side of the pump so that the desired pressure will be maintained.

HIGH–PRESSURE OIL SYSTEM

In the FIRST BRANCH of the high-pressure system, oil from the annulus around the rear end of the oil transfer shaft enters the transfer shaft and passes forward through drilled passages to the intermediate rear and blower cases to the rear main crankcase. It provides lubrication for the valve timing and operating mechanisms of the rear row of cylinders, the rear cam and cam reduction gears, and the rear counterbalance intermediate drive gear and shaft. The pressure oil is metered as it enters the tappets and passes through the hollow tubular push rods into drilled passages in the rockers to lubricate the rocker shafts, the valve clearance adjusting screw inserts, and the ends of the valve stems.

In the SECOND BRANCH, oil from the annulus around the rear end of the oil transfer shaft passes through a passage to an annulus around the rear end of the accessory drive shaft. Oil from this annulus passes to the selector valve, where it is di-

rected through two other passages to operate the high- or low-ratio clutches. From the annulus around the rear end of the accessory drive shaft, passages lead to the main pressure gage connections on the upper right and left sides of the rear case.

In the THIRD BRANCH, most of the oil from the annulus around the rear end of the accessory drive shaft passes through the accessory drive shaft into the rear of the crankshaft. The impeller shaft bearings are lubricated by oil passing through holes drilled in the accessory drive shaft.

The oil passes through drilled passages and a jet in the crankshaft rear section to lubricate the rear main bearing, rear counterbalance, counterbalance spring drive gear parts, rear counterweight roller bushing, and rear master rod bearing.

A retainer plate at each end of the master rod bearing distributes oil to the hollow floating knuckle pins through lugs which fit over bosses at each end of the knuckle pins. The knuckle pins are drilled to direct oil to the articulated rods. The cylinder walls and piston pins are lubricated by a spray of oil thrown from the master rod bearings and knuckle pins.

Oil passing through a drilled passage in the crankshaft center section lubricates the center main bearing.

The front master rod assembly, piston cylinder walls, counterweight roller bushings, and front main bearings are lubricated through drilled passages in the crankshaft front section in the same manner as the corresponding rear parts.

From the crankshaft, the oil continues into the rear end of the propeller shaft. There, two small oil lines extending across the inside diameter of the shaft conduct oil to the two propeller shaft pilot bearings in the crankshaft. A third and larger oil pipe conducts oil through drilled passages in the crankshaft front section to lubricate the front counterbalance and counterbalance spring drive gear parts.

The oil continues forward in the propeller shaft and passes through oil pipes at the reduction drive pinion cage and the pinion shafts. This oil lubricates the reduction drive pinions, pinion bearings, and the reduction drive gear. A spray of oil is played on the reduction drive fixed gear from oil holes in the reduction drive pinion cage.

High-pressure oil to be used in the operation of a hydromatic

propeller is carried to the front end of the propeller shaft by a central tube.

In the FOURTH BRANCH, the oil is taken from the rear end of the propeller shaft through the same pipe which carries oil to the front counterbalance parts. The oil travels through drilled passages in the crankshaft front section and the reduction drive gear coupling to the annulus in the inside diameter of the crankshaft oil transfer bearing.

The oil passes from this annulus through an arm on the bearing to the front end of the upper cam reduction and spark advance gear assembly. From this point, the oil flows through the upper cam reduction gear shaft and is carried through drilled holes in this shaft to the upper cam reduction and spark advance gear assembly bushing in the front support plate.

Through drilled holes in this bushing, the oil passes to an annulus around its outside diameter and thence through passages in the front support plate to lubricate the intermediate drive gears for the magneto, distributor, governor, and counterbalance. As the oil flows through the upper cam reduction gear shaft, it lubricates the various parts of the upper cam reduction and spark advance gear assembly through a series of drilled holes.

When the oil reaches the rear end of the upper cam reduction gear shaft, it is carried through a passage in the front main crankcase. This provides lubrication for the valve timing and operating mechanism for the front row of cylinders, the front cam, the lower cam reduction gear, and the front oil scavenge and booster pump intermediate drive gear. Lubrication of the valve timing and operating mechanism for the front row of cylinders is as described for the rear row of cylinders in the discussion of the first branch.

In the FIFTH BRANCH, oil from the annulus in the inside diameter of the crankshaft oil transfer bearing is carried through a transfer pipe which runs from the bearing to a boss in the right side of the front accessory case. The oil then proceeds through passages in the case to the magneto drive gear, the distributor drive and intermediate drive gears, and the governor. From the governor, the oil is led through passages in the front accessory and front cases and through an oil transfer pipe to

the propeller shaft. Here it is carried forward for use in the operation of a hydromatic propeller.

In the SIXTH BRANCH, oil from the annulus in the inside diameter of the crankshaft oil transfer bearing is carried through a second oil transfer pipe. This pipe runs from the bearing to a boss adjacent to the oil scavenge and booster pump in the front accessory case. The oil then flows through a short passage in the front accessory case to the booster section of the pump.

From the booster, the oil is carried to the booster pump relief valve in the front end plate of the pump and also through passages in the front accessory and front cases to the front end of the torque-indicator master pinion. When the booster pump pressure exceeds 200 p.s.i., the relief valve bypasses oil to the intake side of the booster pump.

After acting on the master pinion, the oil passes through a drilled passage in the front case to a large annulus around the thrust bearing liner seat. From this annulus, it is distributed to the remaining five torque-indicator pistons and to the torque-indicator oil pressure transfer cover.

In the SEVENTH BRANCH, oil from the annulus in the inside diameter of the crankshaft oil transfer bearing is carried through a third oil transfer pipe. This pipe runs from the bearing to a boss in the left side of the front accessory case. The oil then passes through a short passage in the front accessory case to the spark advance operating unit selector valve.

The position of the selector valve determines where the oil shall go from this point. If the valve is in the NORMAL ADVANCE POSITION, the oil passes through a passage in the front accessory housing and is carried through an oil transfer pipe and short passages in the front support plate to the outer side of the spark advance piston. If the selector valve is in CRUISING ADVANCE POSITION, the oil passes through a similar line to the inner side of the spark advance piston.

The SCAVENGE OIL SYSTEM contains a two-section main scavenge pump located in the right rear face of the rear case. The drain oil from the power section and the intermediate rear section is collected in the main sump which is attached to the rear main crankcase and blower case between the No. 9 and No. 11

cylinders. This sump is scavenged by the main section of the main scavenge pump through passages in the intermediate rear and rear cases. A scavenge oil strainer is located in the right passage in the bottom of the intermediate rear case.

The drain oil in the rear section collects at the bottom of the rear case. This drain oil is scavenged through a cored passage, containing a removable strainer, by the small section of the main oil scavenge pump. Both sections of the main oil scavenge pump discharge into the oil outlet passage of this pump.

The front cam compartment drain oil is scavenged through a connecting pipe by the top scavenge section of the oil scavenge and booster pump. Drain oil from the front accessories and the reduction gearing collects at the bottom of the front accessory case and is removed by the middle scavenge section of the pump.

The bottom scavenge section of the pump collects the rocker box drain oil through an external line which is connected to the rocker box drain oil manifold. This manifold is attached to the No. 10 cylinder, and collects the oil through a series of inter-cylinder rubber hose connections.

The oil from the three scavenge sections of the front oil scavenge and booster pump is forced through an external line connected with cored passages in the blower and intermediate rear cases. These, in turn, connect through an internal pipe to the passage at the discharge side of the main scavenge pump.

IGNITION SYSTEM

Ignition is furnished by a dual magneto and two distributors separately mounted on the front accessory housing. The magneto has two breakers, each of which controls current to one distributor. The left distributor supplies current to the rear spark plugs in all cylinders, while the right distributor supplies the front spark plugs. The two distributors and the ignition harness (cast-filled type) form a completely shielded unit to carry the current to the spark plugs. Each distributor incorporates an air pump, and is provided with a steel piping system to pressurize the magneto and the distributors.

CARBURETOR AND FUEL FEED VALVE

The injection-type carburetor with which these engines are equipped, meters fuel in proportion to the mass air-flow to the engine. This mass air-flow is determined by the throttle opening. After being metered to the carburetor, the fuel is carried through the fuel transfer pipe to the fuel feed valve in the intermediate rear case.

The fuel feed valve opening is controlled by the suction of the boost venturi acting on the outboard side of the fuel feed valve diaphragm through a small bleed line, and by metered fuel pressure from the carburetor acting on the inboard side of the diaphragm. A spring on the outboard side of the diaphragm acts to oppose these forces and holds the valve on its seat until the metered fuel pressure is between 3 and 5 p.s.i.

The fuel is discharged from the fuel feed valve at the blower throat. There it is mixed with the air, vaporized by the impeller, passed through the diffuser to the blower rim, and then distributed to the cylinders through the intake pipes and inlet valves.

COMBAT POWER

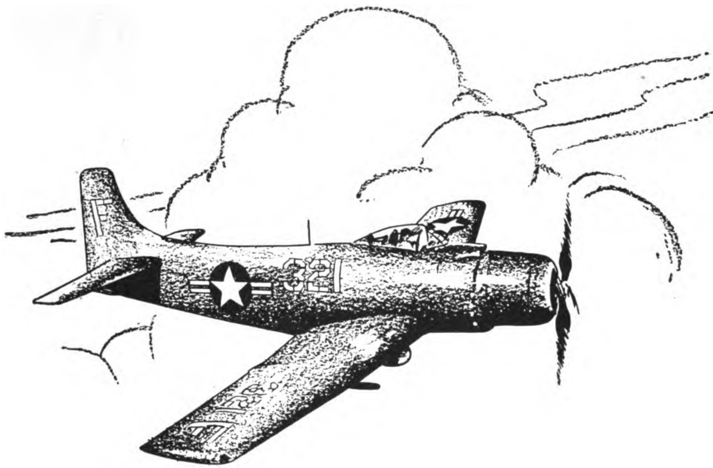
Some models of the R–2800 engines are equipped for WAR EMERGENCY POWER. This is obtained by means of a water injection system developed to permit the engines to be operated safely on currently prescribed military fuels at powers higher than present military power ratings. This extra power is gained by leaning the fuel-air mixture to best power mixture strength and by operating at a higher manifold pressure. To prevent detonation, water is injected to cool the intake charge from the engine supercharger and to retard the speed of the flame travel in the combustion chamber. It is assumed that this emergency-approved power rating will be used only in combat emergency as needed for attack or evasive action.

PROPELLERS

R–2800 engines are equipped with hydromatic propellers. By the addition of special propeller control parts at the thrust bearing cover plate, the engines may be readily adapted for the use of electrically operated propellers.

QUIZ

1. What is the propeller reduction gear ratio? What type of reduction gearing is used?
2. What is the purpose of the torque-indicating system?
3. Where is the automatic spark advance operating unit mounted?
4. Where is the spark advance piston housed?
5. Where is the governor drive gear mounted?
6. How is the crankshaft constructed?
7. In what cylinders are the master rods located?
8. What type valve cams are used in this engine?
9. How many branches does the high-pressure oil system have?



CHAPTER 8

WRIGHT CYCLONE (R–3350) ENGINE

The Wright R–3350 engines are 18-cylinder, twin-row radial, air-cooled powerplants operating in the four-stroke cycle. A two-speed centrifugal type supercharger is employed.

Model R–3350–8 and R–3350–24W engines are basically the same in construction and design. However, a few differences between these models affect the installation, operation, and servicing of the engines. Three views of the R–3350–24W engine are shown in figures 63, 64, and 65.

CRANKCASE

The crankcase of the R–3350 engine is composed of the crankcase front section front half, front section rear half, and front main section, and the supercharger front housing, rear housing, and rear housing cover.

The CRANKCASE FRONT SECTION FRONT HALF (see fig. 66) supports the propeller shaft thrust bearings, thrust nut, and oil seal at the propeller end. The propeller governor oil-transfer sleeve and the stationary reduction gear support are located in the rear diaphragm of this crankcase section.

The CRANKCASE FRONT SECTION REAR HALF (fig. 66) supports the torquemeter booster pump, the left- and right-hand ignition distributors, the front oil pump, and the ignition harness. Bosses are cast integral with the inside of the rear half of the front section. These bosses provide support for the intermediate distributor drive gears, intermediate torquemeter booster pump drive gear, intermediate front oil pump drive gear, and the front oil pump drive shafts.

Early production models or the R–3350–8 engine incorporate a front oil pump with both pressure and scavenge cartridges. Late model R–3350–8 and R–3350–24W engines have a non-cartridge-type front oil pump with scavenge pump gears only.

Machined pads are provided in this section to attach the front oil pump at the bottom, the torquemeter booster pump adapter at the top, and the distributor drive shaft gear supports on the right and left sides. The valve tappet guide bosses for the front-row cylinders are arranged in two staggered rows around the rear circumference of the front section rear half. On the model R–3350–8 engine, the torquemeter pressure pad and torquemeter oil pressure spark advance pad are located, respectively, 45 degrees left and right from the top of the front section rear half. These units are located in the same relative positions on the front section front half on model R–3350–24W engines.

The three CRANKCASE MAIN SECTIONS (fig. 67) are parted in planes at the center of the front and rear rows of cylinders, and are bolted together with internal lugs between the cylinders.

The crankcase front main section supports the front main roller bearing and the front intermediate cam drive gear and pinion support. The crankcase center main section supports the center main roller bearing. The crankcase rear main section supports the rear main roller bearing and the rear intermediate cam drive gear and pinion support. Model R–3350–24W engines have oil jet manifolds of cast construction bolted to the interior of the center main section.

The parting surfaces between the crankcase center main section and the front and rear main sections are sealed with oil seal rings.

or drive and torque- booster pump.

neter oil separator

ition distributor.

sion ignition lead.

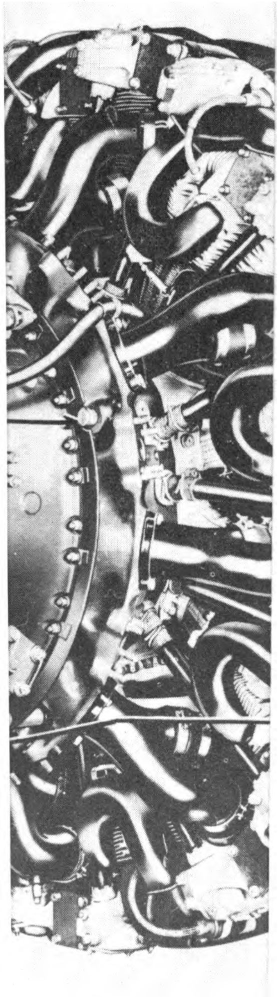
il pump and sump.

l oil pressure tube.

il pump pressure con- alve.

ylinder ignition coil.

il pump strainers and etic drain plugs.



w of R–3350–24W engine.

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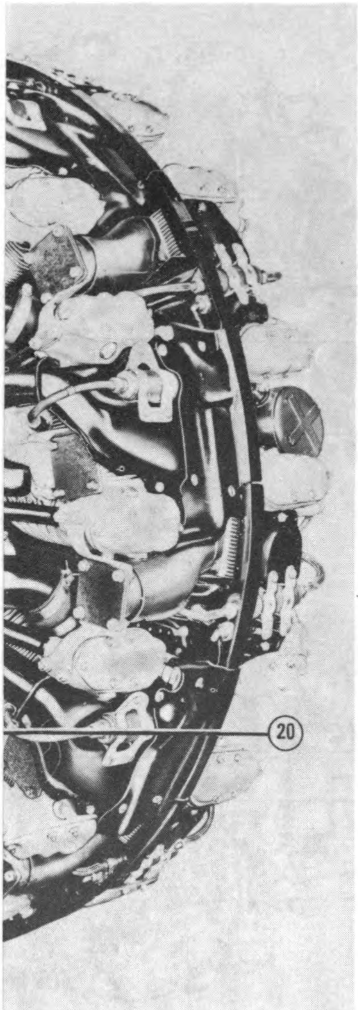

1. Automatic mixture control unit.
2. Carburetor fuel inlet.
3. Primer solenoid..
4. Fuel tube.
5. Right oil tank vent connecti plug.
6. Supercharger rear housing breat tube.
7. Ignition switch and booster c nection.
8. Ignition main primary lead c duit.
9. Supercharger front housing hea connection plug.
10. Right gun synchronizer substit ing cover.
11. Electrical tachometer mount pad.
12. Right fuel pump mounting pad.
13. Mechanical tachometer drive.
14. Oil-in connection.
15. Supercharger clutch control val connection.
16. Rear oil pump pressure reli valve.
17. Rear oil pump and sump straine
18. Oil thermometer connections—c out.
19. External oil scavenge tube.
20. Oil-out connection.

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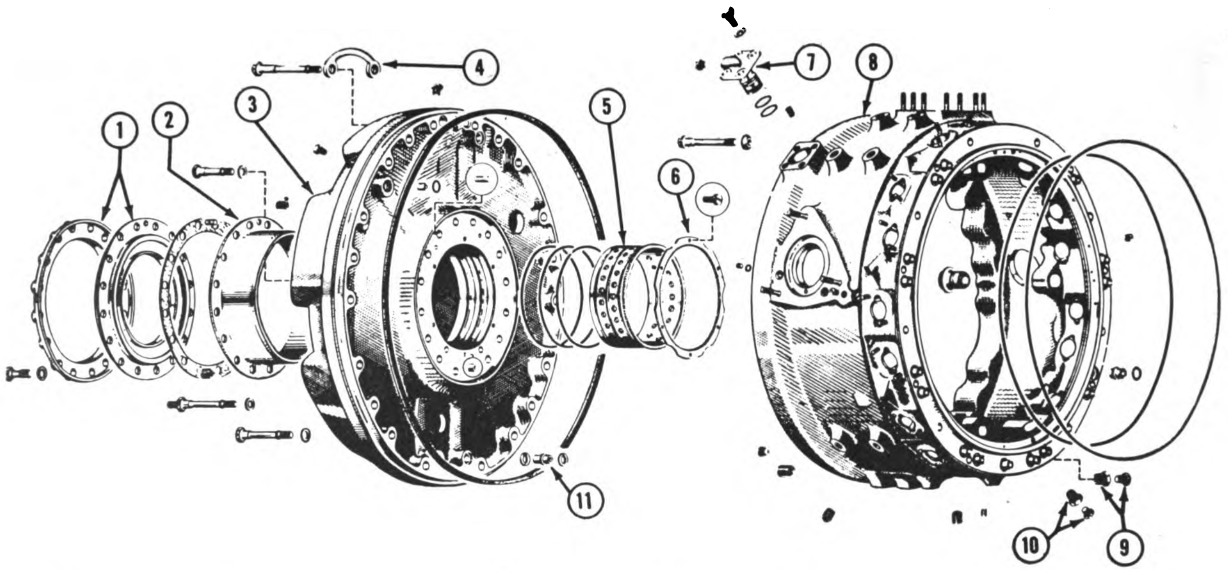
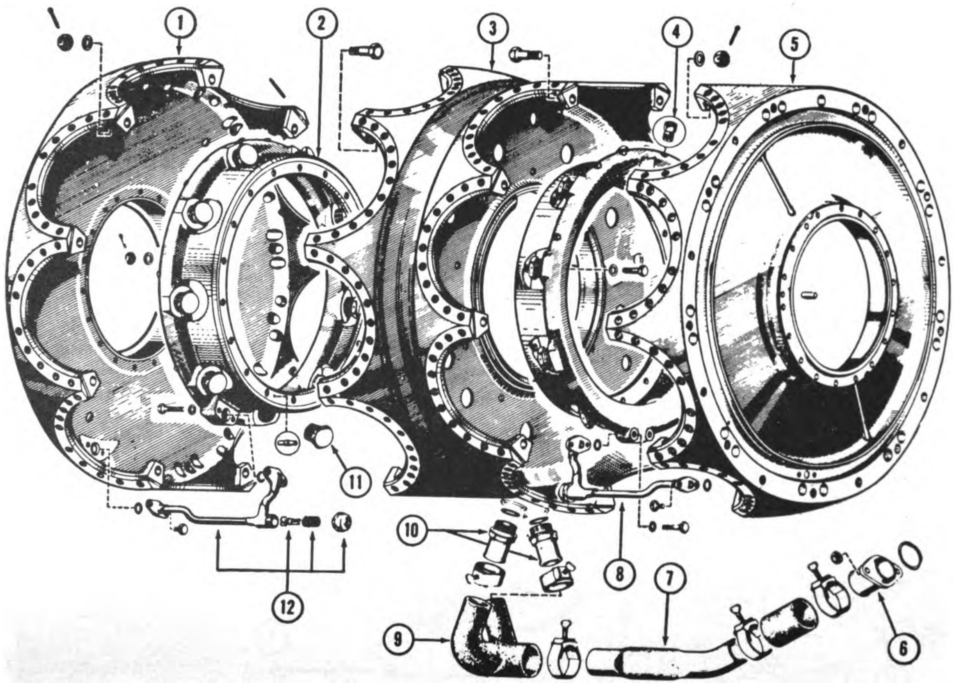


1. Flange spacer and flange.
2. Propeller shaft thrust bearing retainer.
3. Crankcase front section front half.
4. Engine hoist bracket.
5. Crankcase front section front half oil seal sleeve.
6. Crankcase front section front half and propeller shaft oil seal sleeves lock.
7. Torque gage line adapter.
8. Crankcase front section rear half.
9. Pre-oiling plug and bushing.
10. Oil pressure gage connection substituting plug and bushing.
11. Crankcase front section front half to rear half hollow dowel.

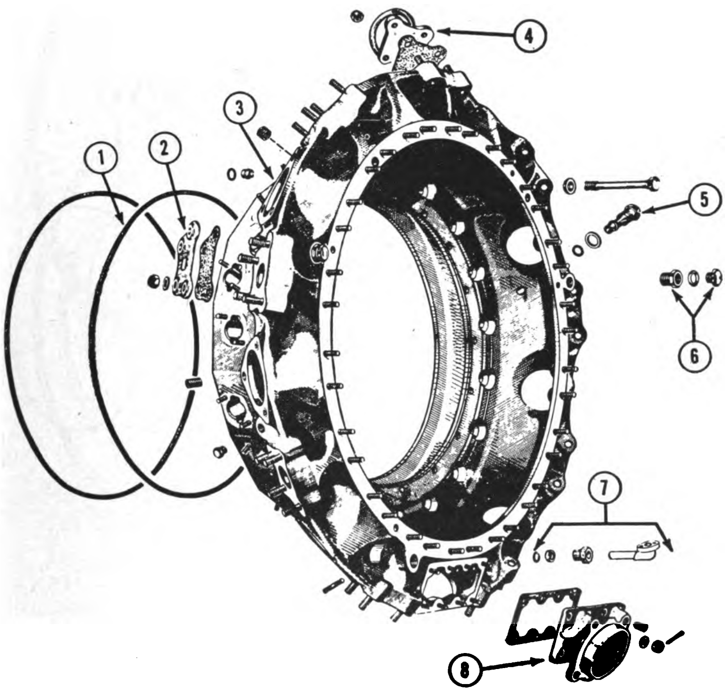
Figure 66.—Crankcase front section.



1. Crankcase front main section.
2. Oil distributing ring.
3. Crankcase center main section.
4. Oil distributing jet.
5. Crankcase rear main section.
6. Oil drain tube connection flange.
7. Oil drain tube.
8. Oil distributing ring transfer tube.
9. Oil drain elbow.
10. Oil drain elbow connection.
11. Oil distributing ring core hole plug.
12. Oil distributing ring transfer tube, check valve, spring, and valve retaining guide.

Figure 67.—Crankcase main sections.

The SUPERCHARGER FRONT HOUSING (see fig. 68) supports the diffuser plate and the valve tappet guides for the rear-row cylinders. Triangular bosses for attaching the nine Siamese intake pipes and pads for nine engine-mounting brackets are evenly spaced on the outer diameter of the housing. The intake pipe flanges are attached to the supercharger front housing with three capscrews. Four studs on each engine mount-



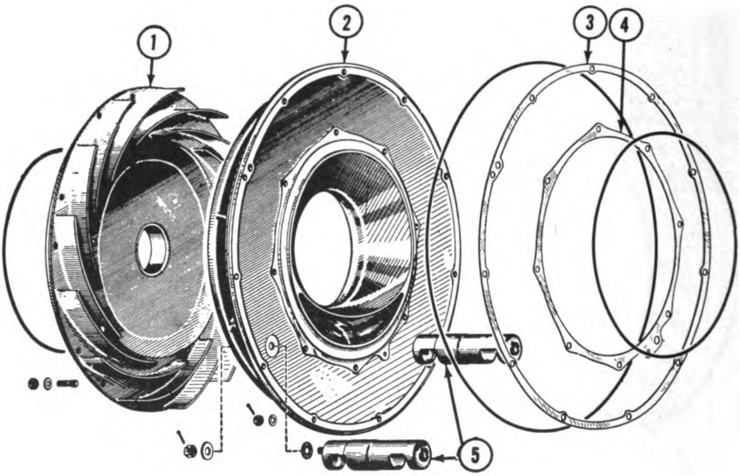
1. Oil seal ring.
2. Engine mounting bracket substituting cover.
3. Supercharger front housing.
4. Engine hoist eye.
5. Heater connection transfer plug.
6. Heater connection bushing and substituting plug.
7. Rear valve tappet annulus pressure oil line tube packing gland, nut, and tube.
8. Oil drain connection.

Figure 68.—Supercharger front housing.

ing pad are used to secure the mounting brackets to the housing.

The supercharger front housing is fastened to the crankcase rear main section with capscrews. The joint is sealed by two seal rings, one on each side of the tappet annulus. Studs located at the rear bolting flange are utilized to attach the supercharger rear housing to the supercharger front housing.

Two through-holes in the lower portion of the supercharger front housing are provided for the two external lines connecting the front and rear oil pumps.



1. Diffuser plate.
2. Impeller shroud plate.
3. Impeller shroud plate to supercharger rear housing outer shim.
4. Impeller shroud plate to supercharger rear housing inner shim.
5. Breather tube.

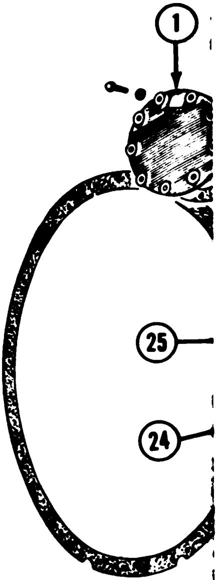
Figure 69.—Supercharger diffuser plate and impeller shroud plate.

The supercharger rear housing (fig. 70) provides surfaces for the following components:

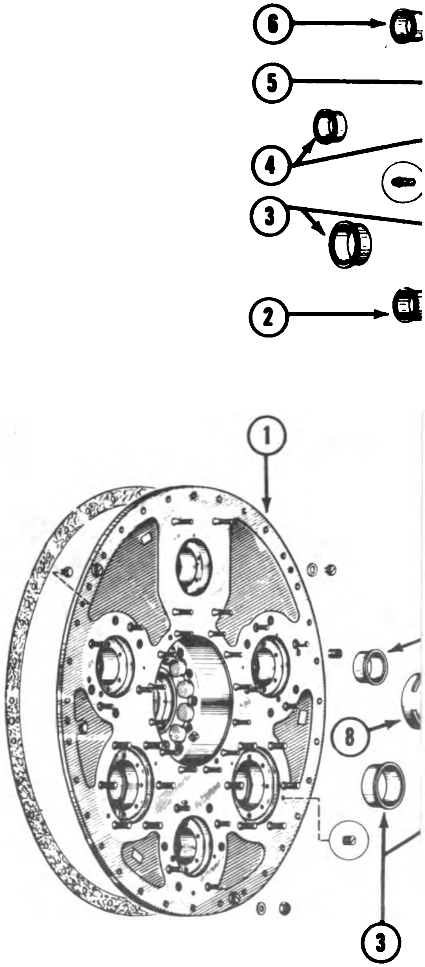
Impeller shroud plate on the front face of the housing.

Impeller drive stationary gear support.

Rear impeller shaft oil seal sleeve.

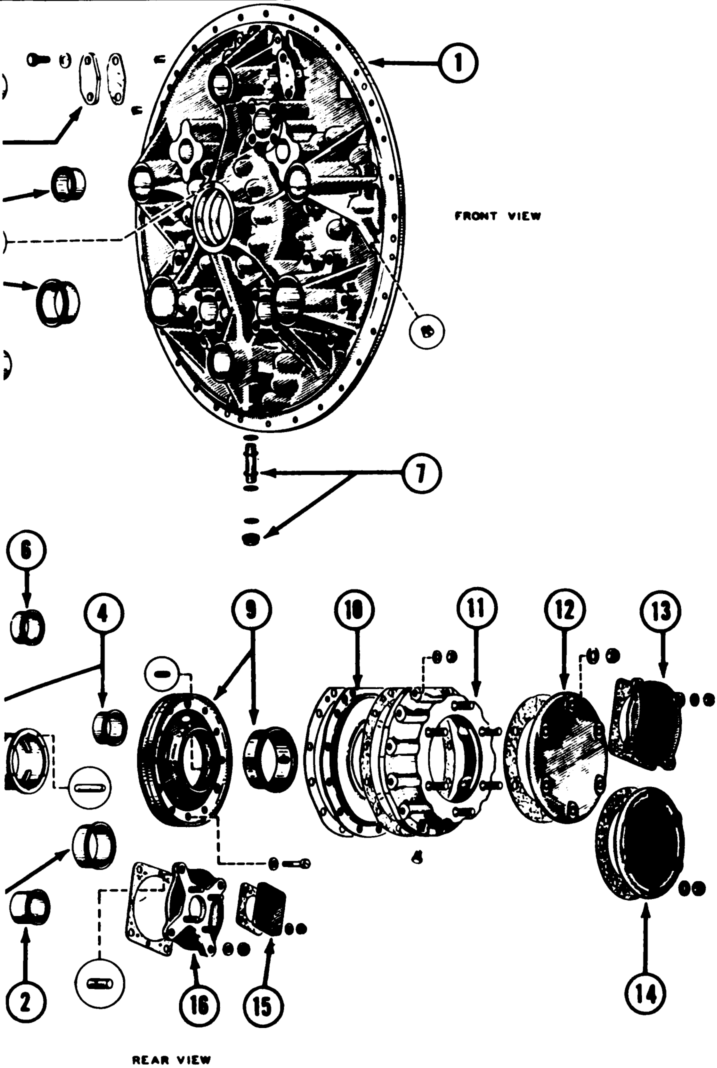


1. Left fuel injecti
2. Breather.
3. Water injection
   stituting plug
4. Water injection
5. Fuel guide vane
6. Fuel guide vane
7. Thermometer b
8. Heater exhaust
9. Breather substit
10. Priming connect
11. Oil tank vent co
12. Breather cover
13. Fuel guide vane
    washers, and
14. Fire seal adapte
15. Supercharger re
16. Breather oil drai



Figur

1. Supercharger rear cover.
2. Oil pump and lower center accessory drive gear bu
3. Right and left generator drive gear bushing.
4. Upper right and left accessory drive gear bushings.
5. Fuel injection pump drive pinion bracket substitut
6. Magneto drive gear bushings.
7. Supercharger rear cover to rear oil pump and sum
   tube and bushing.
8. Accessory drive gear and impeller drive



• 71.—Supercharger rear housing cover.

shings.

ing cover.

oil connection

carrier

9. Accessory drive gear and impeller drive primary pinion carrier support and bushing.
10. Starter coupling thrust ring support.
11. Starter adapter.
12. Starter substituting cover.
13. Upper right and left accessory substituting cover (used at right location only on Model R3350–24W engines).
14. Right and left generator substituting cover.
15. Lower center accessory drive flange accessory substituting cover.
16. Lower center accessory drive flange.

Impeller thrust ring support on the rear wall of the housing.

Fuel pump and tachometer drive shafts support and rear oil pump at the bottom of the housing.

A fuel pump and tachometer drive housing on the right side and a fuel pump drive housing on the left side.

Two circular pads on either side of the housing provide a means for attaching fuel injection pumps. A breather connection pad is located just forward of each injection pad.

A down-draft carburetor is mounted on the pad at the top of the housing, which has an integral induction passage to the impeller. The supercharger drain and return valve is located at the bottom of the induction passage.

The supercharger drain and return valve is designed to return excess liquid fuel into the impeller under various pressure conditions encountered while the engine is in operation. This valve also provides a means of draining excess liquid fuel from the supercharger when the engine is idle.

The SUPERCHARGER REAR HOUSING COVER (fig. 71) has a bearing in its inner diameter which serves as an oil transfer ring and as a support for the impeller drive pinion carrier support and bushing assembly.

Provision is made for mounting the following accessories on the rear cover at the designated locations:

Magneto at top center.

Hydraulic and vacuum pumps a top left and right.

Generators at lower left and right.

Spare accessory at lower center.

Starter in the center.

Bosses on the front face of the cover support the driving and idler gears of these accessories.

Model R–3350–24W engines are equipped with a special rear cover adapter for mounting a manifold pressure regulator and water injection control unit.

TORQUEMETER BOOSTER PUMP AND PROPELLER GOVERNOR DRIVE

The oil supply to the torquemeter cell is obtained from a gear-type booster pump installed on the top center of the

crankcase front section rear half. The torquemeter pump is driven by bevel gears and spur gears from the top intermediate cam drive gear.

Internal splines in the torquemeter booster pump driving gear shaft provide a drive for a constant-speed propeller governor. The torquemeter booster pump upper housing is provided with the proper oil holes for use with either a hydraulically or electrically controlled propeller governor. On model R-3350-24W engines, the torquemeter booster pump is integral with the governor drive. Oil passages supply oil for operation of either a single- or double-acting hydraulic propeller.

DISTRIBUTOR DRIVES

The two bevel distributor intermediate drive gears are secured to two of the front section accessory drive gears by four capscrews in each gear. A spring wire clip retains the distributor drive gear shaft in the distributor drive gear support bushing. Internal splines in the distributor drive gear shaft receive the distributor drive shaft splines.

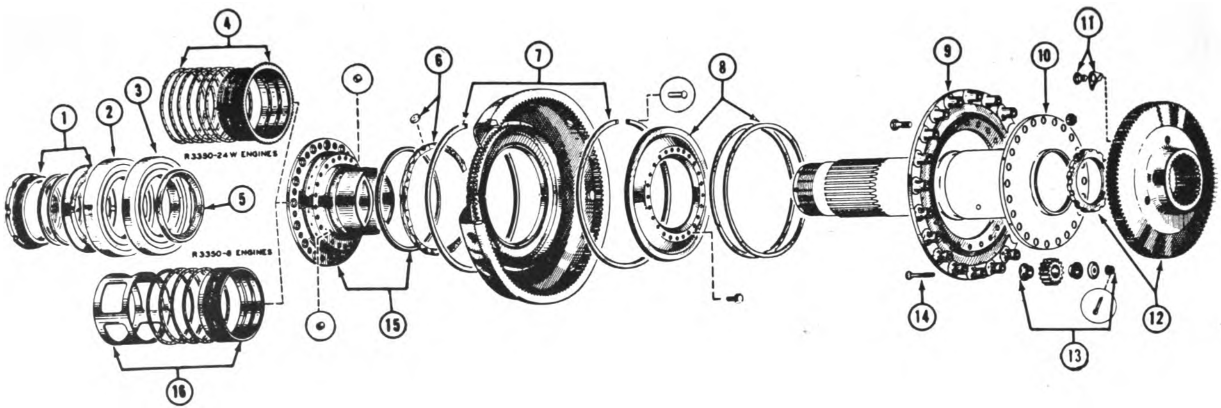
CRANKCASE BREATHING

Breathing is effected in the crankcase sections through holes in the diaphragms of the sections and a series of hollow pins. Breathing is also accomplished through the external oil lines to the rear sump and into the rear section.

Pressure is equalized between the supercharger front housing and rear housing by means of an external tube from the front housing to the connection on the right fuel injection pump substituting cover. Two stand-pipes are located in the bottom of the supercharger rear housing to transmit air from the rear housing to the breather passage around the front of the supercharger rear housing. Air passes from this passage through one of the breather connections located in front of the fuel injection substituting covers.

PROPELLER SHAFT

The propeller shaft has involute splines (size AN 60) machined on its forward end. It has external threads located



1. Thrust bearing nut, oil seal rings, and oil slinger.
2. Thrust ball bearing.
3. Thrust roller bearing.
4. Propeller shaft oil seal sleeve and rings.
5. Thrust bearing spacer.
6. Torquemeter roller cage and roller.
7. Stationary reduction gear and adapter assembly and lock rings.
8. Torquemeter piston and oil seal rings.
9. Reduction gear pinion carrier.
10. Propeller shaft.
11. Reduction driving gear nut lock and bolt.
12. Reduction driving gear and nut.
13. Reduction gear pinion, bushings, washer and nut.
14. Pinion bolt.
15. Stationary reduction gear torquemeter support, bushing, and ring.
16. Propeller shaft oil seal sleeve, rings, and spacer.

Fig. 72.—Torquemeter mechanism and 16:7 propeller shaft reduction gearing.

near the center for the thrust-bearing nut. The area immediately behind the thrust-bearing retaining nut thread provides a journal for the propeller shaft thrust roller and ball bearings. A flange at the rear end of the shaft provides means for attaching the reduction gear pinion carrier. A propeller control oil supply adapter is shrunk into the flanged end of the shaft.

Twenty reduction gear pinions are supported on the pinion carrier trunnions.

PROPELLER REDUCTION GEARING AND TORQUEMETER

Propeller reduction gear systems with crankshaft-propeller shaft speed ratios of either 16:7 or 16:9 may be used in these engine models. Both systems are of the planetary type but differ in construction. Figure 72 is an exploded view of the torquemeter mechanism and 16:7 ratio gearing.

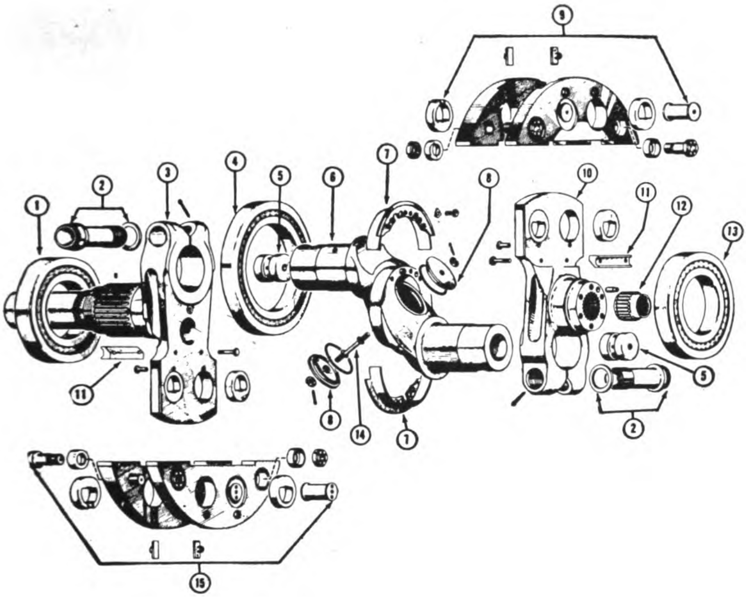
The internal-torquemeter mechanism incorporates the stationary reduction gear and torquemeter support, stationary gear adapter, and torquemeter piston. Steel rollers are held in position by a roller cage and are seated in the conical pockets formed between the stationary reduction gear and torquemeter support and the stationary reduction gear adapter. The torquemeter oil cell is formed between the rear face of the stationary reduction gear adapter and the front face of the torquemeter piston.

CRANKSHAFT

The three sections of the two-row, split-clamp type crankshaft are hollow throughout their length, as illustrated in figure 73.

The three roller-type main bearings support the crankshaft in the crankcase front, center, and rear sections.

Splines are machined on the crankshaft FRONT SECTION for the reduction-drive gear, front cam drive gear, front balanceweight drive pinion carrier, and front balanceweight sleeve. The front main bearing journal is located behind the machined splines.



1. Front main bearing.
2. Crankcheek clamp screw and washer.
3. Crankshaft front section.
4. Center main bearing.
5. Crankpin plug.
6. Crankshaft center section.
7. Center bearing support.
8. Center section oil retainer.
9. Rear counterweight assembly.
10. Crankshaft rear section.
11. Counterweight stop.
12. Accessory drive and starter shaft coupling.
13. Rear main bearing
14. Oil retainer bolt.
15. Front counterweight assembly.

Figure 73.—Crankshaft, model R-3350-24W engines.

A movable, bronze counterweight is attached to the front crank cheek to dampen torsional vibrations.

The two crankpins of the CENTER SECTION are carburized to increase resistance to wear. The center of this section is equipped with two oil retainers and is also provided with a journal for the center main bearing.

The crankshaft REAR SECTION provides a journal for the main bearing, supports the rear cam drive gear and the rear second-order balancer sleeve, and is splined on the inner diameter to receive the accessory drive shaft and starter shaft coupling.

A movable, bronze counterweight is attached to the rear crank cheek to dampen torsional vibrations.

The front, center, and rear MAIN BEARINGS are roller bearings. A roller bearing located directly behind the thrust nut provides radial support for the propeller shaft. The thrust ball bearing is located behind the roller bearing in the steel retainer which is shrunk in the inner diameter of the crankcase front section front half.

Two MASTER RODS, machined to incorporate end seal-type oil seals, are used—one for each row of cylinders. The bore at the crankpin end is designed for a plain bearing of the loose, prefit type. Eight articulated rods are attached to each master rod by means of loose-fitting steel alloy knuckle pins. These pins are retained by a steel locking plate that splines to the master rod bearing.

CAM AND SECOND ORDER VIBRATION BALANCERS

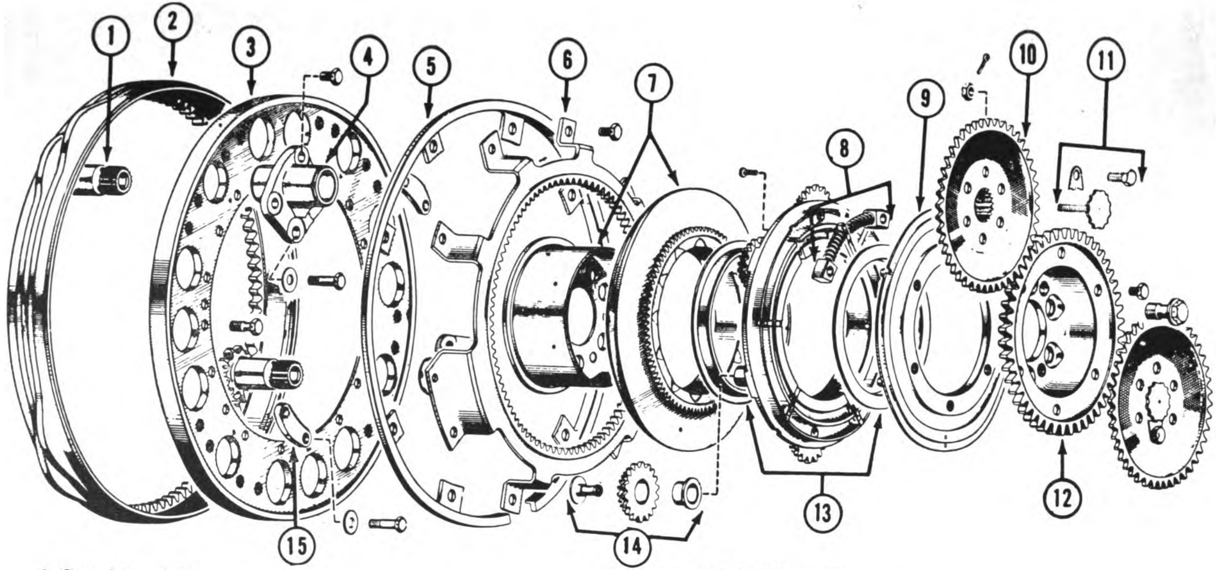
The poppet valve system used in this engine requires two ring-type CAMS. Separate intake and exhaust roller tracks, four lobes on each track, are machined on each cam. The front and rear cams on the model R-3350-8 engines have a 40° overlap. On model R-3350-24W engines, the front cam has an overlap of 70°, and the rear cam an overlap of 90°.

There are two SECOND-ORDER VIBRATION BALANCER mechanisms incorporated in this engine. Each of these mechanisms consists basically of a balanceweight, a stationary gear, a pinion carrier with six pinions, and a balanceweight sleeve. One-half of the concentric type balanceweight is solid, with teeth machined on its front face.

Figure 74 is an exploded view of the rear cam, cam drive, and second-order vibration balancer mechanism.

VALVE MECHANISM

Each cam follower roller revolves on a floating bronze bush-



1. Cam drive pinion.
2. Cam.
3. Cam support.
4. Cam drive pinion bearing.
5. Cam retainer.
6. Balanceweight stationary gear.
7. Balanceweight and sleeve.
8. Balanceweight drive spring, stop, and block.
9. Balanceweight drive spider.
10. Intermediate cam drive gear.
11. Intermediate cam drive gear to cam drive pinion bolt, lock, and lock screw.
12. Cam drive gear.
13. Balanceweight drive pinion carrier and bushings.
14. Balanceweight drive pinion, bushing, and thrust button.
15. Rear cam drive pinion bearing substituting plate.

Figure 74.—Rear cam, cam drive, and second-order vibration balancer.

ing supported in the tappet by a steel pin. The tappet guides are secured in the rear half of the crankcase front section for the front row of cylinders and in the supercharger front section for the rear row of cylinders. The valve tappet assemblies can be removed individually without removing the supporting section. The steel push rod ball sockets are spring-seated in the tappets. The push rods, made of seamless steel tubing with pressed-in steel ball-ends, actuate the rocker arms.

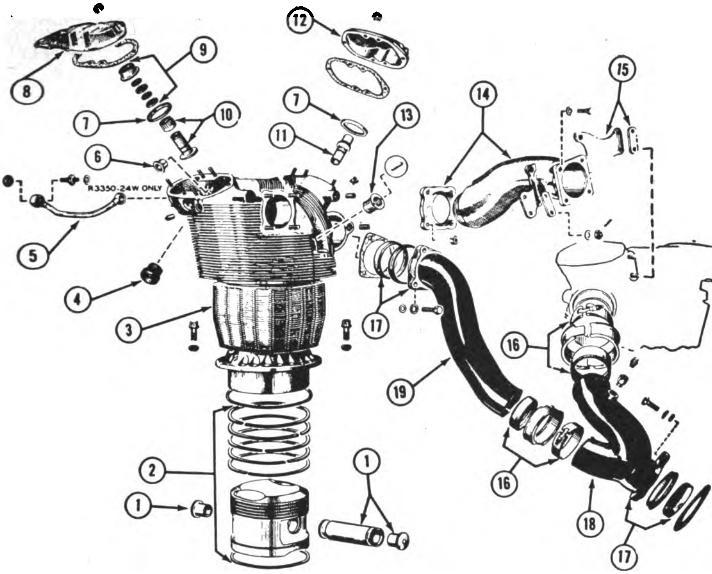
The ROCKER ARMS have an adjustable screw socket at the push rod end and a roller-type contact at the valve tip end. The rocker arm is supported on a steel bolt through a combination ball and roller bearing.

The INTAKE VALVES are of the tulip type with a solid stem. The EXHAUST VALVES are filled with a solution of sodium and mercury for improved cooling. Two springs are used concentrically on each valve to assure positive closing. A slight difference in valve face and seat angles provides a tight seal. Two tapered steel valve locks retain each valve on the upper valve spring washer. Model R–3350–24W engines use flat-head exhaust valves and hour-glass intake valve locks.

CYLINDERS AND PISTONS

The CYLINDER HEADS have closely spaced cooling fins, intake and exhaust valve rocker boxes, and intake and exhaust valve ports. The intake and exhaust valve seats are shrunk into the cylinder heads. The valve guides are located opposite each other and are inclined toward the centerline of the cylinder. There are two spark plug inserts in each cylinder head. Threaded steel inserts and studs provide for baffle attachment. Each rocker box has six studs for attaching the rocker box covers.

The exhaust port flanges of the front-row cylinder heads each have four studs for fastening the shrouded exhaust extensions. The exhaust port flanges of the rear-row cylinder heads each have four studs for fastening the exhaust collector manifold. The front-row cylinder heads have triangular pads for attaching the front intake pipes. A beaded steel sleeve connects the Siamese intake pipes to the rear-row cylinders by



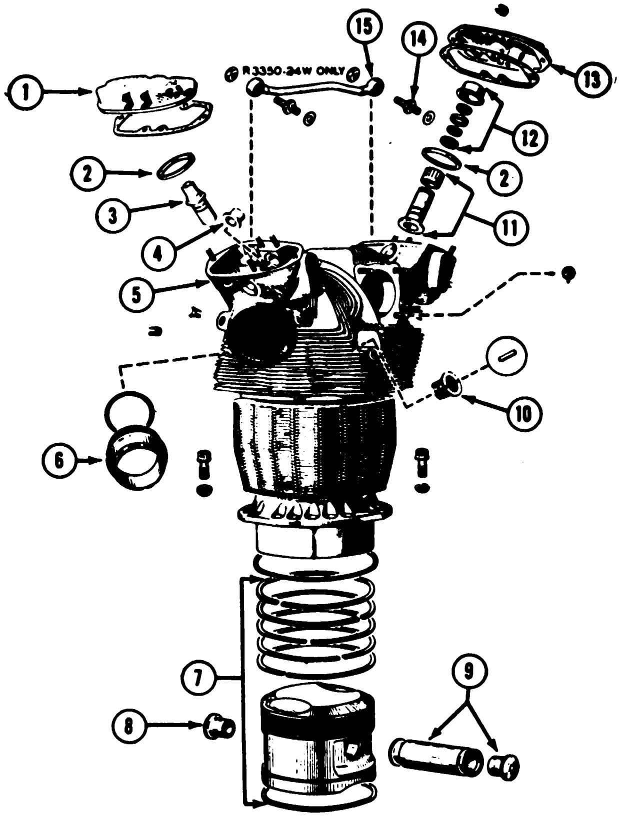
1. Piston pin and plugs.
2. Piston and rings.
3. Cylinder.
4. Push rod housing connection.
5. Rocker lubricating tube.
6. Rocker arm hub bolt bushing.
7. Valve spring outer lower washer.
8. Exhaust rocker box cover.
9. Exhaust valve oil seal spacer retainer, oil seal rings, and spacer.
10. Exhaust valve guide and retainer sleeve.
11. Intake valve guide.
12. Intake rocker box cover.
13. Spark plug insert.
14. Exhaust pipe and flange.
15. Exhaust pipe support bracket and cowl substituting spacer.
16. Intake pipe seal, sleeve, and clamp.
17. Intake pipe flange, sleeve, and packing.
18. Rear cylinder dual intake pipe.
19. Front cylinder intake pipe.

Figure 75.—Front-row cylinder, intake pipe, exhaust pipe, and piston.

means of hoses and clamps. The intake port is located on the right rear side of the front-row cylinder heads, and on the left rear side of the rear-row cylinder heads. Exploded views of front-row and rear-row cylinders are shown in figures 75 and 76.

The cylinder heads of model R–3350–24W and late model R–3350–8 engines incorporate two-piece, self-aligning exhaust valve seats. The valve seat assembly consists of a steel valve

seat and an aluminum-bronze retaining ring. The crossover tubes are attached to the front of the rocker boxes on both rows of cylinders.



1. Intake rocker box cover.
2. Valve spring outer lower washer.
3. Intake valve guide.
4. Rocker arm hub bolt bushing.
5. Cylinder.
6. Intake pipe hose connection.
7. Piston and rings.
8. Piston pin plugs.
9. Piston pin and plug.
10. Spark plug insert.
11. Exhaust valve guide and retainer sleeve.
12. Exhaust valve oil seal spacer retainer, oil seal rings, and spacers.
13. Exhaust rocker box cover.
14. Rocker lubricating tube connection fitting.
15. Rocker lubricating tube.

Figure 76.—Rear-row cylinder and piston.

The CYLINDER BARRELS have integral mounting flanges at the crankcase end, and buttress-type threads at the outer end onto which the heads are screwed and shrunk. The inside of each cylinder barrel is nitrided, and incorporates a slight choke at the head end of the bore. The outside of the barrel is grooved for installing fabricated cooling fins. Twenty capscrews attach the hold-down flange of each cylinder to the crankcase main section. Two special stud extension head screws are provided for attachment of a fire extinguisher bracket at each cylinder location. Model R–3350–24W and late model R–3350–8 engines have an additional hold-down capscrew in each cylinder.

The PISTONS are the full-trunk type, with recesses in the head for intake and exhaust valve clearance.

The piston pins are full-floating. One type of pin is retained in the piston by two plug-type retainers. An early-type pin is retained by two coiled wire retainers which fit into grooves at the outer end of the pin bores in the piston.

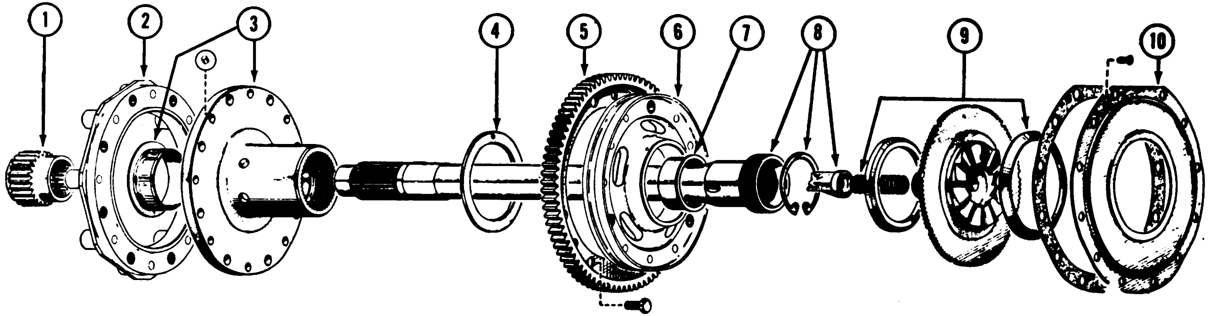
Six ring grooves are provided for the "uniflow"-type piston ring assembly—five ring grooves above the piston pin and one ring groove below. The top three grooves retain wedge-type compression rings. The fourth and fifth ring grooves are drilled for oil drainage and have flat-type oil control rings. The ring groove below the piston pin also accommodates a flat-type oil control ring. The rings above the piston pin scrape down, and the ring below the piston pin scrapes up.

CYLINDER AIR DEFLECTORS

The cylinder barrel and head deflectors are of the close-fitting type, and are held in place by capscrews and clamps located around the cylinder barrels. The head deflectors are designed to form a continuous cowl seal ring around the engine. The front- and rear-row cylinder head deflectors on the model R–3350–24W engines are recessed to house high-tension ignition coils.

ACCESSORY DRIVES

The two generator drives are located on the lower left and right positions of the supercharger rear housing cover. The



1. Accessory drive and starter shaft coupling.
2. Impeller drive primary pinion carrier.
3. Accessory drive gear and impeller drive primary pinion carrier support and front bushing.
4. Accessory drive gear and impeller drive primary pinion carrier support thrust ring.
5. Accessory drive gear.
6. Accessory drive gear and impeller drive primary pinion carrier support.
7. Accessory drive and starter shaft thrust bushing.
8. Accessory drive and starter shaft, retaining ring, and plug.
9. Starter coupling, spring, stop ring, and thrust ring.
10. Starter coupling thrust ring support.

Figure 77.—Accessory drive and starter shaft.

starter drive is located in the center of the cover. The three drives turn clockwise.

Two hydraulic or vacuum pumps are located on the upper right and left positions of the supercharger rear housing cover. Both drives turn counterclockwise.

A spare accessory drive is located at the lower center of the supercharger rear housing cover, and turns clockwise.

All of the drives on the supercharger rear housing cover—except the starter drive—are sealed with kinetic diaphragm-type oil seals. These consist of a molded rubber collar pressed against the drive shaft by a circular cantilever spring.

The fuel pump drive is located on the lower left side, and the dual tachometer drive and alternate fuel pump on the lower right side of the supercharger rear housing. Both units receive their drive from a bevel gear which is splined to the spare accessory drive gear. The fuel pump drive turns counter-clockwise. One tachometer drive turns clockwise and the other turns counterclockwise.

The magneto drive is located on top center of the supercharger rear housing cover.

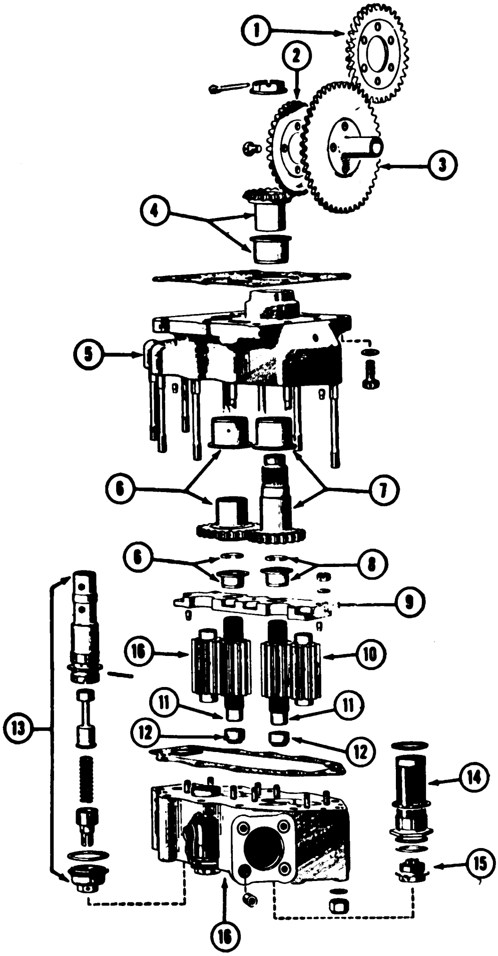
OIL PUMPS AND SUMPS

Early model R-3350-8 engines have two combination pressure and scavenge oil pump and sump assemblies, one at the front and one at the rear of the engine. Model R-3350-24W engines, and late model R-3350-8 engines, have the pressure oil pump located in the rear of the engine, and a scavenge pump in the nose section.

The FRONT OIL PUMP AND SUMP ASSEMBLY on model R-3350-8 engines has two sets of scavenge and one set of pressure gears, all of the spur gear type. These gears are assembled in cartridge housings. This oil pump and sump assembly is attached to the crankcase front section rear half.

The front pump and sump assembly also incorporates a strainer, screen, pressure relief valve, two oil thermometer bushings and substituting plugs, magnetic drain plug, and check valve substituting plug.

The external oil inlet line attached to this assembly leads to the rear pump and sump assembly.



1. Crankcase front section accessory drive gear.
2. Drive intermediate gear.
3. Drive idler gear.
4. Drive shaft intermediate gear and bushing.
5. Front oil pump and sump upper body.
6. Drive shaft driven gear and bushing.
7. Drive shaft gear and bushing.
8. Drive shaft retaining circlet and upper bushing.
9. Suction gear retaining plate.
10. Suction driven gear and shaft.
11. Drive shafts and gears.
12. Drive shaft lower bushings.
13. Oil pressure control valve body, valve, spring, spring seat, and cap.
14. Strainer.
15. Magnetic drain plug.
16. Front oil pump and sump lower body.

Figure 78.—Front oil pump and sump assembly on model R-3350-24W and late model R-3350-8 engines.

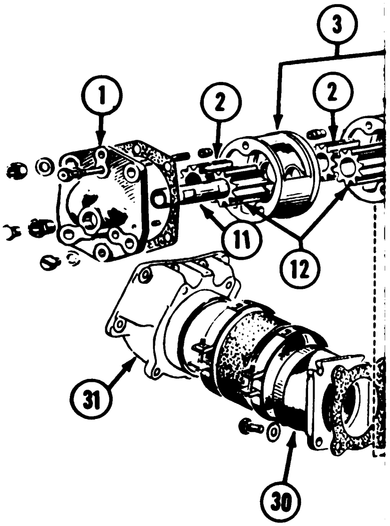


Figure 79.—Rea
3350–8 engines.

1. Gear housing cover.
2. Drive gear.
3. Pressure gear housing and en
4. Drive gear bushing.
5. Drive gear shaft.
6. Drive gear.
7. Intermediate driven shaft gea
8. Drive coupling gear.
9. Oil pump intermediate and a
10. Suction gear housing and end
11. Driven gear shaft.
12. Driven gear.
13. Driven gear oil seal.
14. Oil seal sleeve.
15. Oil check valve substituting p
16. Oil check valve spring and re
17. Supercharger clutch oil contr
18. Rear oil sump strainer.

On model R-3350-24W and late model R-3350-8 engines, there is an external pressure oil line to the front pump for feeding the nose section (fig. 78). The front pump for these engines is of the noncartridge type and contains two sets of scavenge gears and a pressure restrictor valve.

The REAR OIL PUMP AND SUMP ASSEMBLY has two sets of scavenge gears and one set of pressure gears, also of the spur gear type. They are assembled in a cartridge housing. The rear oil pump and sump assembly in R-3350-24W and late model R-3350-8 engines has two sets of scavenge gears and two sets of pressure gears (fig. 79). The pressure gears are assembled in a cartridge housing located in the left side of the pump, and the scavenge gears in a similar housing located in the right side of the pump.

The rear oil pump and sump assembly also incorporates an oil strainer, screen, pressure relief valve, two magnetic drain plugs, check valve, and four oil-thermometer connection bushings and substituting plugs.

The rear assembly is attached to the supercharger rear housing.

LUBRICATION

The LUBRICATION SYSTEM is of the full pressure, dry sump type. On model R-3350-8 engines, all moving parts except the following are lubricated by oil under pressure: piston rings and pins, cylinder walls, crankshaft main bearings, propeller shaft roller and ball bearings, and the valve-operating mechanism for the intake valve on cylinders below the horizontal centerline of the engine. These parts are lubricated by splash or by gravity feed.

On model R-3350-24W engines, all moving parts are lubricated by oil under pressure except the piston rings and pins and cylinder walls (lubricated by oil from two pressure-jet manifolds), and the crankshaft main bearings and propeller shaft roller and ball bearings (lubricated by splash and by gravity feed).

On early model R-3350-8 engines, oil enters the oil inlet connection on the rear oil pump. From that point, the oil takes two paths. Part flows through the connection and into

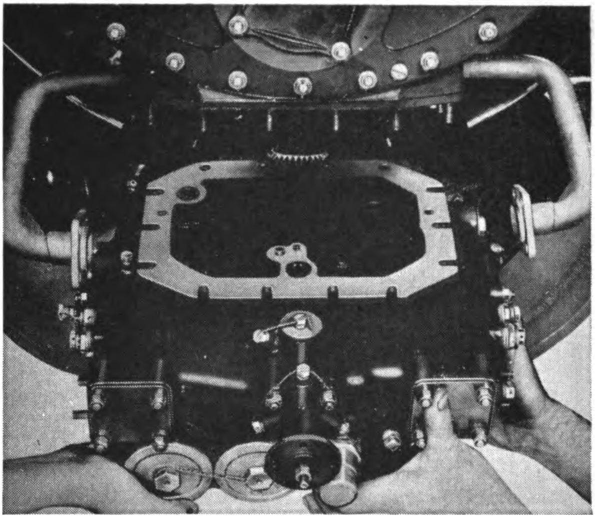


Figure 80.—Removing rear oil pump and sump assembly.

the external oil inlet line to the front oil pump. The rest of the oil is pumped by the pressure gears into the oil strainer. A portion of the oil is led from the strainer through a dowel into a passage in the supercharger rear housing, from whence oil flows through an external line and a passage in the supercharger front housing to the rear valve tappet annulus.

From this annulus, oil flows through a series of drilled passages to the valve tappet assemblies and push rods for all cylinders above the horizontal centerline of the engine. A tube from the annulus carries oil to the rear cam and cam drive pinion bearings.

Some of the oil travels through the strainer in the rear oil pump, bypasses the pressure relief valve, and flows through a large drilled passage in the pump housing. Two small passages branch off from the large passage. One passage carries oil to lubricate the rear oil pump drive shaft bushings. The other passage carries oil to a small hole in the flange of the pump.

Oil flows through this hole to a passage in the tachometer

and fuel pump drive shaft support to lubricate the tachometer, fuel pump, and spare accessory drive gear bushing. From the annulus around this bushing, oil flows through the hollow shafts to lubricate the outer bushings.

On model R–3350–24W and late model R–3350–8 engines, oil enters the inlet connection to the rear oil pump, and flows through the pressure gear housing to a passage which leads to the two rear strainer assemblies. From these assemblies, the oil takes two paths. One path leads from the left strainer and through the external oil inlet line to the front oil pump. The other path leads from the right strainer through the pressure relief valve to a drilled passage in the pump housing.

The oil branches into three paths from this passage. One path leads to the left side of the pump, from which the oil flows through a hollow dowel in the pump flange into a passage in the supercharger rear housing. From this point, oil flows through an external tube to another passage in the supercharger front housing which leads to the rear valve tappet annulus.

Nine drilled holes lead from the annulus to the rear-row exhaust tappet assemblies, from which oil passes through the push rods to the exhaust rocker box, and through the rocker crossover tube to the intake rocker box.

On model R–3350–24W engines, oil also flows from the rear tappet annulus through a jet in the oil distributing ring transfer tube to the rear oil distributing ring. Nine jets in this ring spray oil out to the rear cylinders. Another oil tube from the rear valve tappet annulus directs oil to the rear cam and cam drive pinion bearings.

The second path from the drilled passage in the pump housing leads through a small hole in the flange of the pump to a passage in the tachometer and fuel pump drive shaft support. From this point, the tachometer, fuel pump, and spare accessory drive gear bushing are lubricated. From the annulus around this bushing, oil flows to the tachometer and fuel pump drive shaft bushing and to the alternate fuel pump drive shaft inner bushing. From there it passes through the hollow shafts to the outer bushings.

The third and major path from the rear oil pump passage

directs oil through the oil transfer tube into a large passage in the supercharger rear housing cover. A small passage leads to the lower center spare accessory drive bushing. The large passage continues through the cover and forms a Y. A portion of the oil passes through a metering jet to a large annulus in the center of the cover. Oil flows from this annulus through drilled passages to all the remaining accessory drive gear and idler gear bushings.

The other sections of the Y leads through the passage in the rear cover to an annulus in the accessory drive gear and pinion carrier support bushing. From here the oil passes to the annulus formed by the accessory drive gear and pinion carrier rear and front bushings. From this annulus, oil flows through radially drilled passages in the center of the support to lubricate the pinion carrier trunnions and bushings.

Oil enters the hollow center of the accessory drive and starter shaft through four holes near the rear end of the shaft. A drilled passage leading to an oil flat permits lubrication of the impeller shaft rear bushing. Drilled holes at the front end of the accessory drive and starter shaft permit lubrication of the impeller shaft front bushing.

Oil flows past the bushing into the space between the accessory drive and starter shaft and impeller shaft. Two drilled holes in the impeller shaft allow this oil to flow through the shaft to four holes in the impeller thrust spacer, where it lubricates the bearing surface between the spacer and the impeller shaft thrust ring.

Oil continues forward through the accessory drive and starter shaft to the inside of the rear crankshaft. A passage is drilled from the inside of the crankshaft to an annulus on the outer surface which mates with an annulus on the inner surface of the rear balanceweight sleeve. Six drilled passages conduct oil from the annulus to the outside of the balanceweight sleeve. Six additional holes are drilled through the front of the sleeve so that oil may flow to the clearance between the inside of the front of the sleeve and the outside of the rear came drive gear.

Six other holes in the sleeve lead to holes in the balance-

weight pinion carrier bushing. Six radially drilled passages in the carrier supply oil to lubricate the balanceweight pinion buttons and bushings.

Another passage leads through the crankshaft rear section, crankshaft center section, and the rear crankpin plug to the rear hollow crankpin. On model R-3350-8 engines, oil flows through the clearance between the inner surface of the crankpin and the outer surface of the plug to an annulus on the plug's outer surface. This annulus serves as reservoir for oil which is sprayed through an oil jet in the rear crankpin to lubricate the cylinder walls, piston pins, and crankshaft bearings.

Three tubes in the rear crankpin conduct oil to the outside surface of the crankpin for lubrication of the master rod bearing. Oil passes along the bearing to the oil seal, to the knuckle pin locking plate, through drilled holes in the knuckle pin lock screws, to the hollow center of the knuckle pins. From here, oil flows to two flats on the outer surface of the pins to lubricate the connecting rod bushing. Additional lubrication of the cylinder walls, piston pins, and crankshaft bearings is provided by splash from the master rod and knuckle pin bearing. Oil continues forward through the crankshaft into the front master rod bearing, knuckle pins, cylinder wall piston pins, and crankshaft bearings in the same manner as described for the rear.

Oil flows out of the front crankpin plug through two holes in the crankshaft front section into the hollow center of the crankshaft front section. Two drilled holes carry oil from the crankshaft front section through four holes at the front of the front balanceweight sleeve. Holes in the balanceweight pinion carrier bushing and six radially-drilled passages in the carrier lead the oil to the balanceweight pinion buttons and bushings. Eight drilled holes in the rear of the balanceweight sleeve carry oil to lubricate the front balanceweight.

On model R-3350-8 engines, oil flows out the front end of the crankshaft front section to the space between the crankshaft and the propeller control oil-supply adapter. Oil flows through six holes in the front of the adapter into the hollow propeller shaft and an additional six holes lead to the propeller control oil-supply front support. Oil also flows through 27

passages in the propeller control oil-supply adapter into the space between the adapter and the propeller shaft. Oil is also supplied to this space from the front oil pump.

On early model R–3350–8 engines, oil enters the front oil pump from the external oil inlet line, passes the pressure gears of the pump, and goes on to the oil filter. Most of the oil flows from the pump through a drilled passage in the crankcase front section to a large horizontal passage across the bottom of the housing. From this large passage (on all model R–3350–8 engines), two passages in the crankcase front section rear half diaphragm carry oil up to the space between the diaphragm and the stationary gear support.

Three holes in the propeller shaft lead to the space between the shaft and the propeller control oil-supply adapter. Oil flows from this space through six radially-drilled passages in the propeller shaft flange to an annulus on the reduction gear pinion carrier. From here, oil passes through 20 radially drilled holes in the carrier to lubricate the reduction gear pinion bushing.

Oil is also carried from the horizontal passage in the bottom of the crankcase front section rear half through a drilled passage to the front tappet annulus. It flows from this annulus through a series of drilled holes to lubricate the valve tappet assemblies and push rods of all cylinders above the horizontal centerline of the engine and all exhaust valves of the cylinders below the horizontal centerline of the engine.

Oil also flows from the front tappet annulus through drilled passages to lubricate the following components: crankcase front section accessory drive idler gear bushings, governor and torquemeter booster pump drive gear, two distributor drive gears, and the front oil pump drive gear. Two oil passages lead from the tappet annulus to the governor and torquemeter booster pumps.

A tube carries oil from the front tappet annulus to lubricate the front cam and cam drive pinion bearings. High-pressure oil returning from the governor pump flows through a passage in the crankcase front section rear half to an indexing passage drilled down through the diaphragm in the crankcase front section front half.

The high-pressure oil passes through eight holes in the crankcase front section oil seal sleeve, 16 holes in the propeller shaft oil sleeve, an annulus around the outside surface of the propeller control oil-supply adapter, and three passages in the adapter to the propeller control oil-supply tube to come to the piston which actuates the propeller mechanism if a hydromatic propeller is used.

On model R-3350-24W engines, oil flows out the front end of the crankshaft and passes through five holes in the propeller control oil-supply adapter. Ten holes leading from the five holes in the adapter carry oil to the space between the adapter and the inside surface of the propeller. Six holes in the propeller shaft flange carry oil to an annulus on the reduction gear pinion carrier. From here it passes through 20 radially-drilled holes in the carrier to lubricate the reduction gear pinion bushings.

On model R-3350-24W engines and late R-3350-8 engines, oil flows into the left side of the front oil pump inlet connection through the external oil line from the rear oil pump. It passes through a passage along the left side of the pump lower body and through the oil pressure control valve.

Oil flows from the pressure control valve through a hole located in the front center of the pump upper body and into the horizontal passage across the bottom of the crankcase front section rear half. Two passages leading from the horizontal passage carry oil through the crankcase front section front half to the space between the crankcase front section front half diaphragm and the stationary reduction gear and torquemeter support.

Flow of oil continues through two holes in the propeller shaft to the space between the inside surface of the propeller shaft and the outside surface of the propeller control oil-supply adapter.

Another passage leads from the horizontal passage, across the bottom of the crankcase front section rear half, to the front tappet annulus. Nine drilled holes from the front valve tappet annulus carry oil to the front-row exhaust tappet assemblies, through the push rods to the exhaust rocker boxes, and through the rocker crossover tubes to the intake rocker boxes.

On model R-3350-24W engines, oil flows from the front tappet annulus through a jet in the front crankcase main section oil distributing ring transfer tube and into the front oil distributing ring. Nine jets in this ring spray oil out to the front-row cylinders.

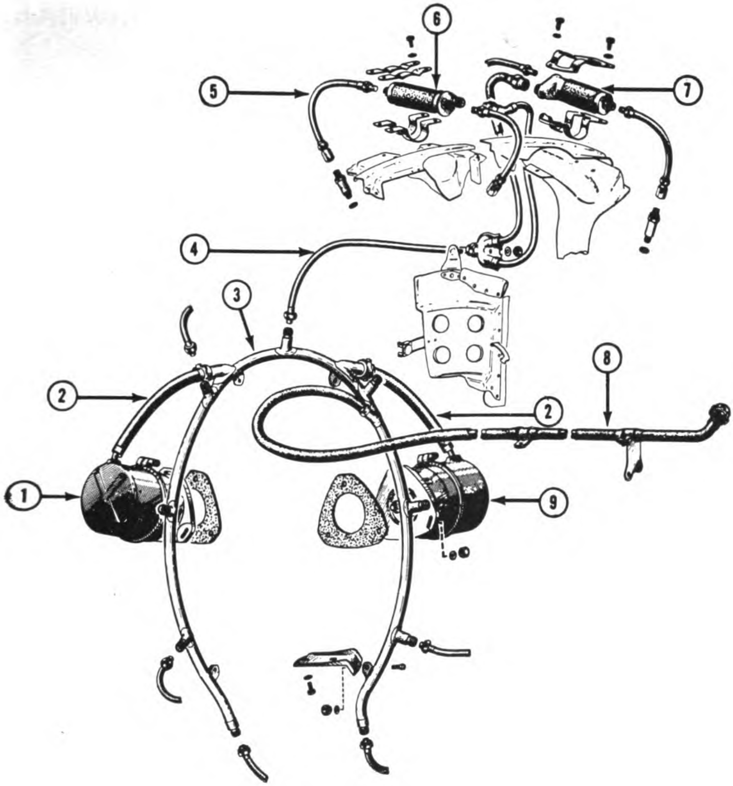
Drilled passages also carry oil from the front tappet annulus to lubricate the crankcase front section accessory drive gear bushings, the governor and torquemeter booster pump drive gear, the two distributing gears, and the front oil pump drive gear. Two oil passages lead from the front tappet annulus to the governor and torquemeter booster pumps. A tube carries oil from the front tappet annulus to lubricate the front cam and cam drive pinion bearings.

High-pressure oil returning from the governor pump flows through two passages in the crankcase front section rear half to two indexing passages drilled through the diaphragm in the crankcase front section front half.

Oil from the center passage flows to an annulus on the inside surface of the diaphragm. From there it passes through 24 holes in the crankcase front section diaphragm oil seal sleeve, 24 holes in the propeller shaft oil seal sleeve, two holes in the propeller shaft, and 10 passages in the propeller control oil-supply adapter to the center of the propeller control oil-supply tube.

Oil from the passage to the left of the center flows to the annulus on the inside of the diaphragm. From this point, it travels through 24 holes in the crankcase front section diaphragm oil seal sleeve, 24 holes in the propeller shaft oil seal sleeve, two holes in the propeller shaft, and 10 passages in the propeller control oil-supply adapter to the space between the inside surface of the propeller shaft and the outside surface of the propeller control oil-return sleeve.

Oil flows from the torquemeter booster pump to a passage in the crankcase front section rear half which mates with a passage in the crankcase front section front half. This passage runs through the diaphragm in the crankcase front section front half to an annulus around the front face of the stationary reduction gear and torquemeter support. Oil from the annulus passes through 25 holes in the support and 25 holes in the



1. Left distributor.
2. Ignition cable manifold to distributor lead.
3. Ignition cable manifold.
4. Low tension lead to coil.
5. High tension lead to spark plug.
6. Front cylinder coil assembly.
7. Rear cylinder coil assembly.
8. Magneto to ignition cable manifold main primary lead.
9. Right distributor.

Figure 81.—Ignition cable assembly, distributors, coils, and spark plugs on model R-3350-24W engine.

torquemeter piston to the cell between the torquemeter piston and the stationary gear adapter.

All return oil flows to the oil outlet connection on the rear oil pump. The oil from the crankcase front section front and rear halves and most of the oil from the crankcase front main section drains into the front sump through drilled or cored pas-

sages and hollow pins. It is pumped to the oil-out connection on the rear pump through an external oil line by two sets of scavenge gears.

Some of the oil from the crankcase front main section, and the oil from the crankcase center and rear main sections, drains through two connections on the bottom of the crankcase center main section into an external tube which carries it to the supercharger front housing.

On early model R–3350–8 engines, oil from the supercharger rear housing drains, along with the oil from the crankcase main section, through the oil sump drain connection into the lower portion of the rear sump. All return oil in the supercharger rear housing drains into the upper portion of the rear sump.

On model R–3350–24W and late model R–3350–8 engines, the supercharger front housing, crankcase main section, and the supercharger rear housing all drain into the same location in the sump.

Oil from the supercharger front housing and crankcase center main section drains through the oil sump drain connection, while oil from the supercharger rear housing drains through the top of the sump housing. The return oil is pumped by two sets of scavenge gears to the oil-out connection on the rear pump, and from this connection to an external tank.

IGNITION

The low-tension, high-altitude ignition system consists of the following components:

A MAGNETO delivering only low-tension current impulses.

A MAIN CONDUIT, which is part of the ignition harness assembly, carrying primary current from the magneto to two distributors.

A HARNESS to conduct the current to the nine induction coils on model R–3350–8 engines, and to 18 induction coils on model R–3350–24W engines.

Thirty-six HIGH-TENSION LEADS which transmit high-tension current from the induction coils to the spark plugs.

Model R–3350–8 engines are equipped with Scintilla DLN–7 magnetos (fig. 83), while model R–3350–24W engines use

Scintilla DLN-9 magnetos (fig. 82). These magneto assemblies consist essentially of a housing, two rotating magnets, four primary coils, and a junction box. The two four-pole, rotating magnets are mounted on the same shaft between two ball bearings.

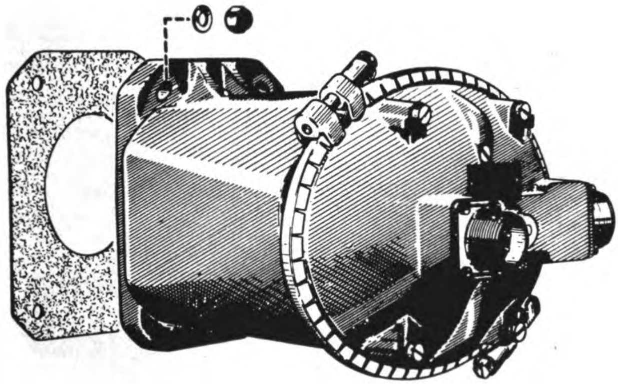


Figure 82.—Scintilla DLN-9 magneto used on model R-3350-24W engines.

Since the poles of one magnet are staggered in relation to the poles of the other magnet, there are eight consecutive current impulses per revolution of the magneto shaft. The magneto turns one and one-eighth times the engine crankshaft speed to make nine dual primary impulses for each revolution of the engine crankshaft.

From each of the four primary coils there is a lead to the junction box mounted on the rear of the magneto. There are three connections on the junction box—one to the booster coil, one to the ignition switch of the airplane, and one for the main conduit.

In the HARNESS ASSEMBLY, the main conduit contains the four main primary wires and two booster wires. These wires pass from the main conduit into the harness manifold. Two primary wires pass through the distributor head. The left and right distributor heads are part of the harness assembly.

The breaker assemblies are located in the bodies of the two identical DISTRIBUTORS. These assemblies are actuated by two

nine-lobe compensated cams keyed to the distributor shafts between two ball bearings. The right distributor fires the front plugs in each cylinder, and the left distributor fires the rear plugs.

INDUCTION COILS and HIGH-TENSION LEADS complete the system. Eighteen primary wires from each distributor lead to the harness manifold and are carried—four through each of the nine secondary leads—to the nine induction coils mounted between the front-row cylinder heads on model R-3350-8 engines, and to the 18 secondary coils on model R-3350-24W engines.

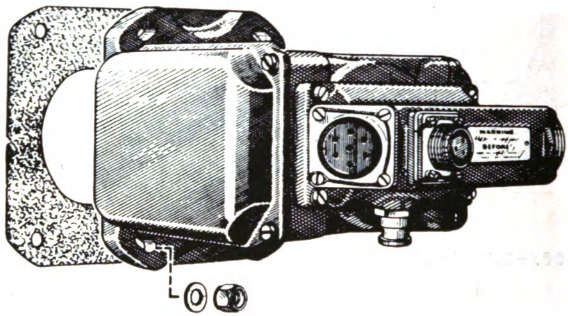
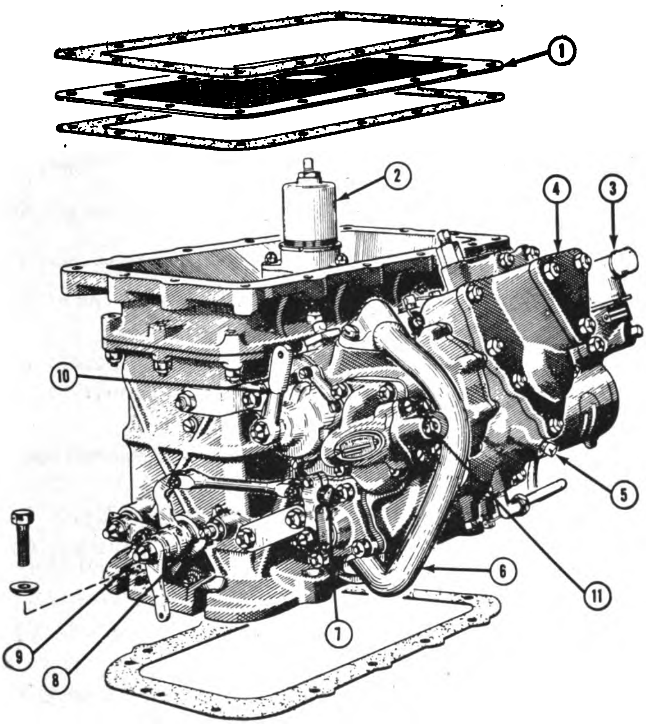


Figure 83.—Scintilla DLN-7 magneto used on model R-3350-8 engines.

The current is transformed at the induction coils from low voltage, and transmitted to the spark plugs through high-tension leads. Four high-tension leads from each coil carry current to the spark plugs of a front-row cylinder and a rear-row cylinder on R-3350-8 engines. On model R-3350-24W engines, two high-tension leads from each coil carry current to the front and rear spark plugs in the cylinders on which the coil is mounted.

FUEL INDUCTION

The conventional-type carburetor is used in these engines. Fuel is metered under pressure into the supercharger inlet and the fuel-air mixture is delivered through the INDUCTION SYSTEM to the cylinders. Figure 84 shows the Stromberg PR58Q2 carburetor used on the model R-3350-24W engine.



1. Carburetor air inlet screen.
2. Automatic mixture control unit.
3. Electric primer.
4. Fuel inlet connection substituting cover.
5. Fuel pressure gage connection plug.
6. Fuel tube.
7. Idle mixture adjustment.
8. Idle speed adjustment.
9. Throttle shaft.
10. Manual mixture control lever.
11. Derichment tube substituting plug.

Figure 84.—Stromberg PR58Q2 carburetor used on model R–3350–24W engines.

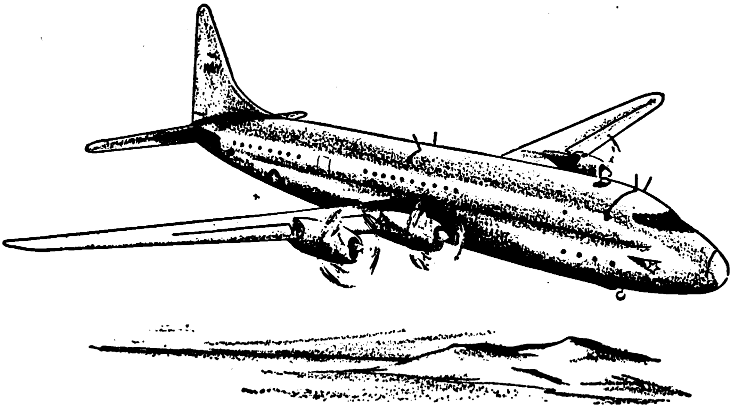
WATER INJECTION POWER CONTROL SYSTEM

A water injection and manifold absolute pressure regulator system is provided on the model R–3350–24W engine. This system furnishes combat power in low- and high-supercharger drive ratios in excess of the power available without water injection. Combat power is obtained by over-boosting the en-

gine to a point where severe detonation would be encountered. This detonation is suppressed by the injection of water directly into the supercharger inlet passage.

QUIZ

1. Where are the valve guide tappet bosses for the front row of cylinders located? Where is the magneto mounted?
2. What is the source of the oil supply for the torquemeter cell?
3. What is the size of the spline machined on the forward end of the propeller shaft?
4. Briefly describe the crankshaft.
5. How are torsional vibrations in the crankshaft dampened?
6. Briefly describe the piston.
7. Where are the hydraulic or vacuum pump drives located? In what direction do the drives turn?
8. What type lubrication system is used on these engines?
9. What parts make up the low-tension, high-altitude ignition system?



CHAPTER 9

PRATT & WHITNEY (R–4360) ENGINE

Models R–4360–2, –2A, –4, –4A, –18, –27, –35, and –35A engines, manufactured for the Navy by Pratt & Whitney, are four-row radial, air-cooled powerplants. (See fig. 85.) From front to rear, the five major sections of the engine case are the propeller shaft case, the magneto drive case, the crankcase, the blower case, and the accessory drive case.

The 28 cylinders in this engine are helically arranged around the crankcase in four rows of seven cylinder banks. The five-section crankcase houses a five-cam system and supports a one-piece crankshaft incorporating four crankpins.

Ignition is furnished by seven magnetos whose timing is controlled by a two-position spark advance system. In our discussion, we will use the model R–4360–4 and R–4360–27 engines for the purpose of general description. Figure 87 shows a cutaway view of the engine.

PROPELLER SHAFT CASE SECTION

The PROPELLER SHAFT CASE supports the propeller shaft and its thrust bearing, the propeller governor and front oil pump drives, and the front oil pump. Bosses with bearings for supporting two gun drives project internally from each side of the case.

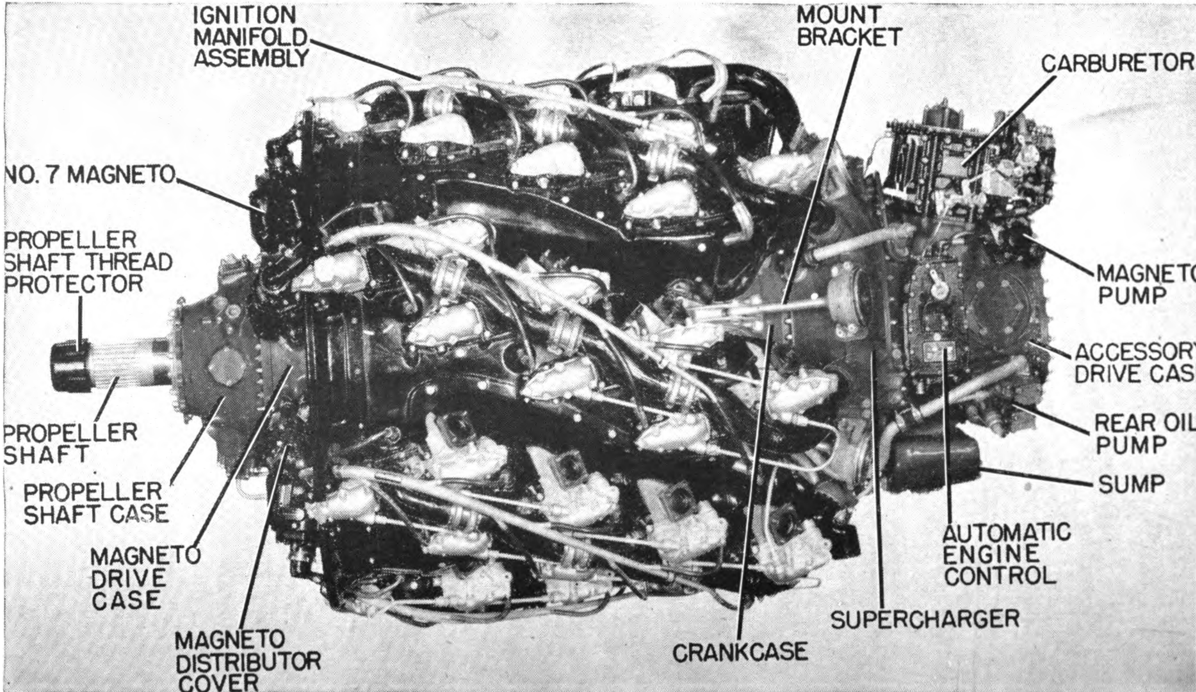


Figure 85.—Left view of R–4360 engine.

The PROPELLER SHAFT, which incorporates a 60A spline at its front end for mounting the propeller, supports an oil transfer bearing and the reduction drive pinion cage. The rear end of the shaft is supported by two steel-backed bronze bearings in the front end of the crankshaft. The main body of the shaft is supported by the thrust bearing.

The bore of the propeller shaft is separated into two compartments by a propeller shaft plug. Oil from the rear compartment lubricates the reduction gearing, and boosted oil is directed into the front compartment.

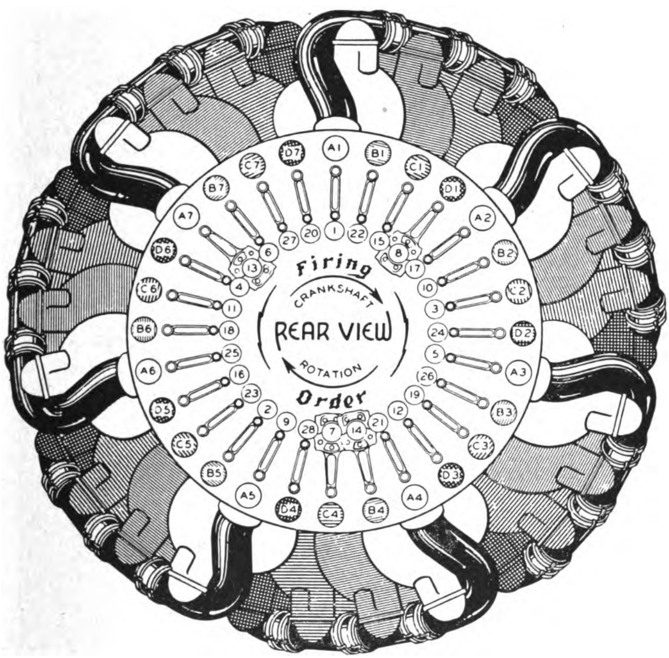


Figure 86.—Cylinder arrangement and firing order.

The 16 pinions of the 0.425 reduction drive and the 11 pinions of the 0.381 reduction drive are of the spur planetary type. Each pinion rotates around a steel race which is slotted to engage the pinion shaft dowel pin, thereby preventing the race from spinning. The ends of each pinion shaft are supported by the pinion shaft front and rear supports.

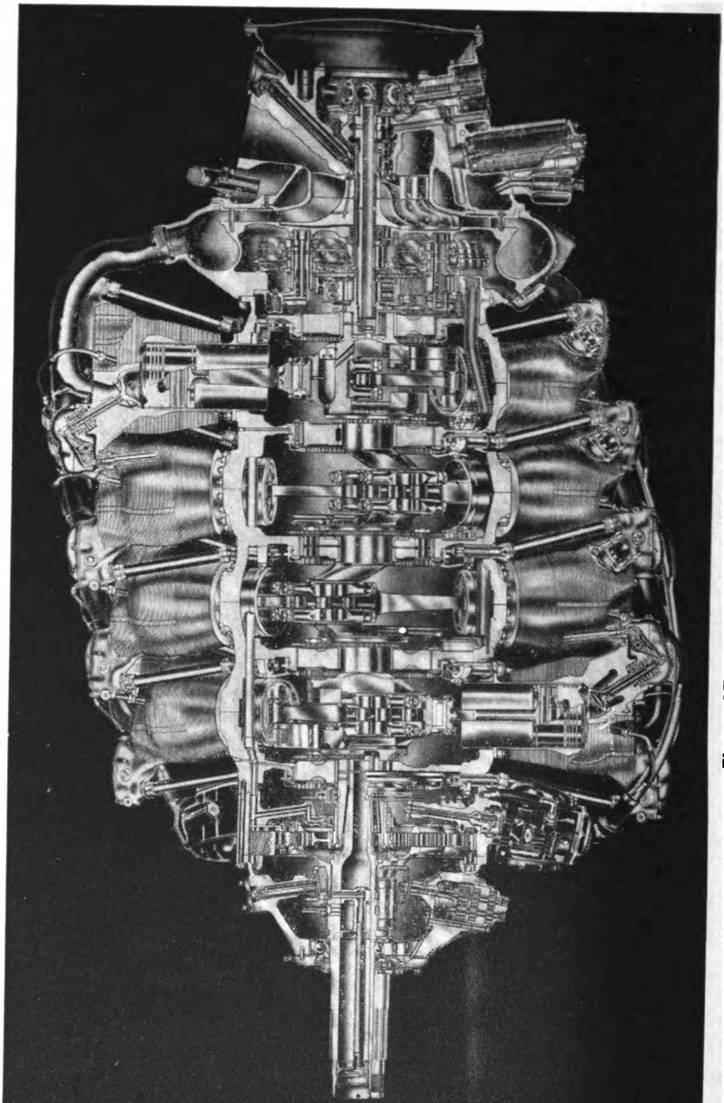


Figure 87.—Cutaway view of engine.

The pinion cage consists of the pinion shaft front and rear supports. The front support is pressed onto the propeller shaft rear splines and locked in place by a spanner nut. The rear support is secured to the rear ends of the pinion shafts. The front accessory drive gear (a bevel ring gear attached to the front of the front support) drives the propeller governor and front oil pump drive gears.

The PROPELLER GOVERNOR DRIVE gear is supported by a flanged bushing in each end of a boss projecting internally from the upper part of the case. End movement of the gear is limited by a snap ring in the groove at the outer end of the gear shaft. The propeller governor drive gear is driven by the front accessory drive gear.

The FRONT OIL PUMP extension shaft rotates within its support which is attached to studs in the bottom inside wall of the case. The front oil pump drive gear is splined to the inner end of the extension shaft, and is driven by the front accessory drive gear. The outer end of the extension shaft is coupled to the front oil pump drive shaft.

The front oil pump housing consists of four sections bolted together to form three scavenge chambers. The pump is mounted in the bottom of the propeller shaft case section. The housing supports the oil pump drive shaft and the idler shaft.

The three gears which are keyed to the drive shaft mesh with the three gears mounted on the idler shaft. The top idler gear is pinned to its shaft. Each pair of gears operates within one of the scavenge chambers of the pump. The top chamber scavenges oil from the propeller shaft case and magneto drive case sections; the center chamber scavenges oil from the front rocker box sump; and the bottom chamber scavenges oil from the front cam compartment.

The PROPELLER SHAFT OIL TRANSFER BEARING, which floats on the propeller shaft, is held in position by the two governor oil transfer pipes. The rear pipe is rigidly supported by one of the internally projecting bosses of the case. Engine high-pressure oil is boosted by a dual-action governor and then transmitted through the two transfer pipes and the transfer

bearing into the propeller shaft and thence to the propeller, where it is used for hydromatic propeller control.

The PROPELLER SHAFT THRUST BEARING is a ball bearing with a split inner race. The outer race of the bearing is seated in the propeller shaft case liner. The thrust bearing cover retains the outer race of the bearing against the rear flange of the liner, while the thrust bearing nut retains the inner race against a spacer which is seated against a shoulder on the propeller shaft.

The thrust bearing nut carries two oil seal rings which contact the liner in the thrust bearing cover. The thrust bearing cover spacer is installed between the thrust bearing cover and the outer race of the bearing. An oil slinger is held between the thrust bearing nut and the bearing inner race. The bearing supports the front of the propeller shaft and transmits propeller thrust from the shaft to the case.

MAGNETO DRIVE CASE SECTION

The MAGNETO DRIVE CASE is mounted on the front crankcase. Arranged radially around the outside of the case are seven

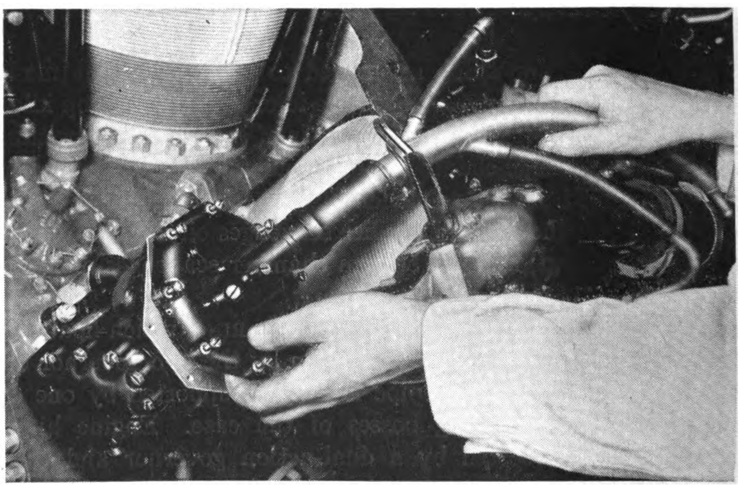


Figure 88.—Ignition manifold and cable assembly.

pads for mounting the magnetos. The drive shafts of the magnetos are supported in the web of the case. The magneto drive case houses the propeller shaft reduction gears and the spark advance system. The helical splines in the wall of the magneto drive case engage a fixed gear equipped with torquemeter pistons. The case is provided with pads for mounting a torquemeter transmitter and a torquemeter booster pump.

The PROPELLER SHAFT REDUCTION GEAR train is constructed as follows:

The reduction drive gear is splined to the reduction drive gear coupling, and locked in place by two snap rings. The coupling, in turn, is splined to the front end of the crankshaft. In those engines not provided with torquemeters, the fixed gear is attached by its flange to the front rim of the magneto drive case web. In engines provided with torquemeters, the fixed gear engages the helical splines in the wall of the magneto drive case.

The reduction drive pinions are driven by the reduction drive gear. As they rotate within the fixed gears, they turn the pinion supports and hence the propeller shaft at 0.425 times or 0.381 times the crankshaft speed, depending upon the engine model.

The CRANKSHAFT OIL TRANSFER BEARING, which is lined with babbitt, floats on the reduction drive gear couplings. The chromium-plated end of a boss, integral with the top of the bearing, fits into an elbow which is attached to the front face of the magneto drive case web, thus limiting any movement of the floating bearing.

A telescoping pipe, consisting of an inner pipe and an outer pipe mounted on opposite ends of a small spring, is installed between the elbow and the pipe boss on the transfer bearing. Oil flows into the elbow through a hole in the web of the magneto drive case and then passes through the telescoping pipe and into the oil transfer bearing.

The oil then flows through holes in the coupling, crankshaft, and propeller shaft into the bore of the propeller shaft where it joins the oil conducted to the propeller shaft by the crankshaft. This maintains sufficient oil pressure in the front of the engine.

The MAGNETO DRIVE PINION CAGE, which is splined to the front end of the crankshaft just behind the reduction drive gear coupling, supports the six magneto drive compound pinions. The front and larger gear of each compound pinion meshes with the spark advance gear, while the smaller gear of each compound pinion drives the spur teeth of the magneto intermediate drive gear.

The four SPARK ADVANCE CYLINDERS, each housing a spring-loaded piston, are numbered right to left from 1 to 4. Special oil transfer studs secure the pairs of cylinders to the rear face of the magneto drive case web. The spark advance gear, which regulates the timing of the magneto drive system, has two arms, each of which is attached to a pair of pistons by two piston links. Adjustable stops control the outward travel of each piston.

When no pressure oil is in the cylinders (as is the case before the engine is started), the spark advance gear will be in the starting (5°) spark advance position. After the engine starts, high-pressure oil from the annular groove behind the flange of the reduction drive fixed gear is diverted to the No. 1 and No. 4 cylinders through their oil transfer studs. The pressure oil, counteracting the spring pressure, forces the pistons to turn the spark advance gear to the normal (20°) spark advance position.

The No. 2 and No. 3 cylinders may be utilized to obtain still another spark advance position. There is, however, no requirement for an additional spark advance position in these engines, and there is no provision for actuating the pistons in the No. 2 and No. 3 spark advance cylinders.

The TORQUEMETER BOOSTER PUMP is a small, gear-type pump mounted on the rear face of the magneto drive case web. It is driven by a shaft and splined coupling which takes its power from the top front cam reduction gear. The pump boosts engine oil pressure for operation of the torquemeter.

In the TORQUEMETER GEARING, diagonally cut splines in the magneto drive case engage similar splines on the reduction drive fixed gear so that engine driving torque produces a component thrust toward the rear on the fixed gear. To counteract this thrust there are 40 small pistons placed in holes in the

rear face of the gear. The piston heads rest on a steel ring attached to the case.

Engine oil, under high pressure from the booster pump, is admitted to the pistons through drilled passages in the fixed gear. The operation of the master piston decreases the oil flow when the fixed gear moves toward the front, and increases it when the fixed gear moves toward the rear. Thus, the fixed gear is balanced between the thrust component of the engine torque and the thrust caused by the oil pressure on the pistons.

The piston oil pressure—which is directly proportional to the engine driving torque—is transferred to the inner side of the transmitter diaphragm. A low viscosity oil is used between the outer side of the diaphragm and the cockpit pressure gage. The gage provides a direct indication of the propeller driving torque.

The TORQUEMETER TRANSMITTER is a diaphragm contained between a cover and the magneto drive case. It prevents the engine oil from mixing with the low viscosity oil used in the torquemeter pressure gage line, thus preventing congealing in the line with resultant sluggish operation of the pressure gage.

CRANKCASE SECTION

The five sections of the crankcase are identified as the front, front intermediate, center, rear intermediate, and rear crankcase. Each section supports one journal of the crankshaft and a part of the valve-actuating mechanism.

Four CRANKCASE OIL PUMPS scavenge oil from the front intermediate, center, rear intermediate, and rear cam compartments and transmit it toward the rear through pipes and drilled passages in the lower part of the crankcase. Each of the pumps is mounted on the front wall of one of these compartments.

The 56 VALVE TAPPET GUIDES are supported in the holes provided for them in the crankcase. The front and rear crankcases each support seven radially positioned guides, while the center crankcase and front and rear intermediate crankcases each support 14 radially positioned guides. Each guide houses and provides a bearing surface for a valve tappet. A cam

roller is secured to the inner end of each tappet by a silver-plated roller pin.

Each of the five TAPPET OIL MANIFOLDS consists of a series of pipes and connections joined together to form a circuit. The pipes of each manifold fit snugly in the connections which are attached by special oil transfer screws to the tappet guide bosses and a feeding oil passage. Part of the pressure oil which passes forward through drilled passages and transfer pipes in the upper part of the crankcase enters each manifold through the feeding oil passage. This oil is transmitted to the rocker boxes through the valve tappets and push rods.

CAM DRIVES

Each of the five identical cams has an internal gear and two external tracks. Each track has three lobes. The cam rollers are attached to the valve tappets, and contact the cam tracks. The rollers and tappets are actuated by the cam track lobes.

The two retainers for each cam are located diametrically opposite each other on the front face of the cam bearings, and are secured by the bolts which secure the cam bearings and the crankshaft bearing support retainers. The retainers for the front intermediate, center, and rear intermediate cams have a cutout for clearing the cam reduction pistons and a slot for engaging the front ends of the crankshaft bearing support spacer. These slots function jointly with the slots in the crankshaft bearing support retainers to prevent rotation of the supports.

Each cam is driven by two cam reduction gear and pinion assemblies at one-sixth the speed of—and opposite in direction to—the crankshaft. Each of the 10 cam reduction gears is splined to the shaft of its pinion, which is supported by two leaded bearings.

The bearings for the front and rear pinions are located in the front and rear crankcase webs, while those for the front intermediate, center, and rear intermediate pinions are located in the corresponding crankshaft bearing supports. Except for the lower rear cam reduction gear, each lower cam reduction gear drives a crankcase oil pump.

The rear cam drive gear is a one-piece gear splined to the accessory drive shaft coupling and held in place by a spanner nut which is secured by a spring-loaded screw. The remaining four cam drive gears are of two-piece construction, split along the centerline of diametrically opposite tooth spaces, and attached directly to the crankshaft by screws and bolts. Each of the cam drive gears drives two cam reduction gears.

CRANKSHAFT

The one-piece crankshaft is dynamically balanced, and has four crankpins and five supporting bearing journals. The center journal has flanged ends which locate the crankshaft axially. Each crankpin is angularly positioned $192\frac{6}{7}°$ clockwise around the longitudinal axis of the shaft with reference to the crankpin behind it.

The hollow crankshaft is fitted with plugs and pipes which conduct pressure oil to the master rod and crankshaft bearings. Nozzle-type oil slingers and small drilled holes adjacent to the crankpins provide oil squirts for improved cylinder wall lubrication. The accessory drive shaft coupling is splined to the rear end of the crankshaft and anchored to the crankshaft rear plug.

The crankshaft is equipped with two large counterweights, one suspended from the crankshaft front cheek and one from the rear cheek. In addition, two small fixed counterweights are bolted to the crankshaft.

The crankshaft is supported at each of its bearing journals by a prefitted, steel-backed, leaded silver bearing. The front and rear bearings are of one-piece construction, and are located in the small bores of the corresponding crankcase sections. The front end of the front bearings supports the magneto intermediate drive gear.

The front intermediate, center, and rear intermediate crankshaft bearings are of two-piece construction. The flanged center bearing transmits thrust from the crankshaft to its center bearing support. Each split bearing is held together by a similarly split crankshaft bearing support. The halves of the latter are bolted together by studs and serrated locknuts.

Four MASTER and LINK ROD ASSEMBLIES—each basically consisting of a master rod and six link rods—drive the crankshaft. Each of the four master rods and master rod bearings are of the split type. Each bearing, prefitted and keyed to its master rod, is a steel-backed, leaded silver bearing. The component parts of each master rod assembly—the master rod and cap—are bolted together around the corresponding crankpin. Silver-plated shims are provided between the parting faces of the master rod and its cap to prevent galling.

Each link rod is of the I-section type. A bronze bushing in the larger, or piston, end of the rod accommodates the piston pin. The smaller end of each link rod is attached to the master rod by a knuckle pin. Two link rods are anchored to each master rod and four are anchored to its cap.

The knuckle pins are classified as fully intersected, partially intersected, and non-intersected types, according to the extent or absence of the cutouts providing clearance for the master rod bolts.

CYLINDERS

An aluminum muff in which barrel cooling fins have been machined, and an aluminum head with integral braced cooling fins, are shrunk onto each of the 28 identical cylinder barrels. (See fig. 89.)

Each cylinder is secured by 16 studs to the corresponding cylinder mounting pad on the crankcase. Two integral valve rocker boxes are diametrically opposed in the top of each head. The rocker box covers are secured by washers and self-locking nuts to their studs in the rocker boxes. Each rocker box is equipped with a push rod cover nut adapter.

The exhaust pipe coupling in the exhaust port of each cylinder is equipped with a steel liner and four studs for securing the exhaust pipe. The intake port is located between the rocker boxes and has four studs for intake manifold attachment.

The spark plug openings, located in the left and right sides of each cylinder head, have stainless steel helicoil spark plug inserts.

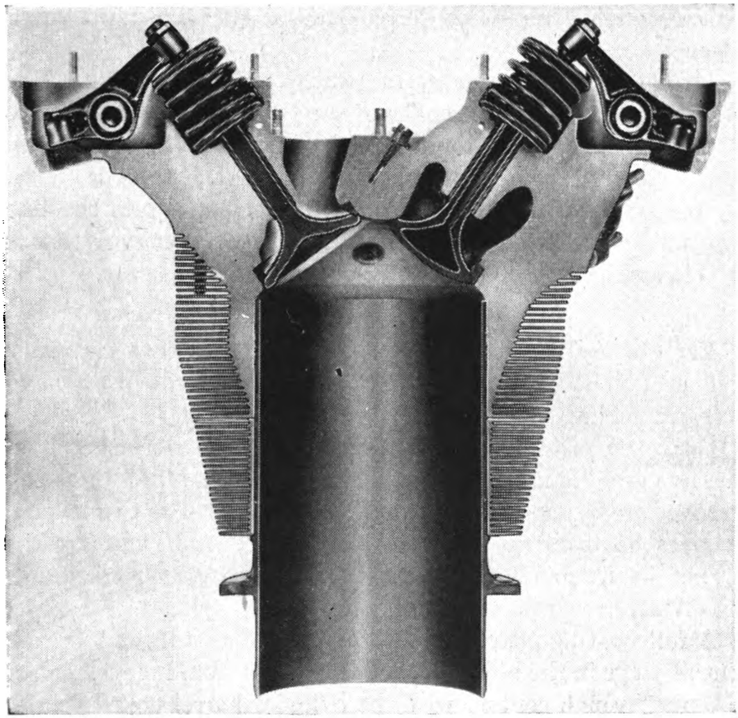


Figure 89.—Sectional view of cylinder.

A bronze inlet valve seat, a steel exhaust valve seat, and two bronze valve guides are installed in each cylinder head.

VALVE MECHANISM

The tubular push rods are enclosed in single-piece tubular covers which are secured to the tappet guides and the adapters in the rocker boxes. The push rods and covers connected to the inlet rocker boxes are slightly shorter than those connected to the exhaust rocker boxes.

Each VALVE ROCKER is supported on its rocker shaft by the bronze bearing in its bore and by a removable steel sleeve which fits around the shaft. The solid steel rocker shaft, extending through the rocker box, is supported at each end by a flanged steel bushing and is secured by a nut. A valve-

clearance adjusting screw and locknut are located in the valve of each rocker.

Each cylinder has an INLET and an EXHAUST VALVE. The solid inlet valve is the smaller of the two. The exhaust valve is partially filled with sodium for improved cooling, and has a stellite seating surface to prolong its life. Each valve is seated by the action of two concentric springs which operate between two washers. The upper washer is secured to the valve stem by conical locks.

PISTONS

Each of the 28 pistons has a domed head with a clearance cut-out for the valve. The internal surfaces of the piston have integral cooling fins.

Cast iron piston rings with butt-type gaps are installed in the five grooves in the piston skirt. The rings in the three top grooves are wedge-shaped compression rings. The two bottom grooves have oil drain holes. Two oil control rings are installed in the fourth ring groove, while the bottom groove has an oil scraper ring.

A full-floating piston pin anchors each piston to its link rod. Dural plugs in the hollow steel pin limit the axial movement of the pin through contact with the cylinder barrel bore.

ROCKER SUMPS

All of the lower rocker boxes drain through interconnecting external pipes into two rocker sumps. The front sump is attached to the leading edge and main deflectors between D3 and D4 cylinders. It is scavenged by the center chamber of the front oil pump.

The rear sump is attached directly to A5 cylinder inlet rocker box in place of a rocker box cover, and is scavenged by the smaller scavenge chamber of the rear oil pump. A removable basin in the rocker box end of the rear sump provides a pool of oil for A5 inlet valve guide lubrication.

CYLINDER DEFLECTORS

The pressure-type deflectors are so arranged that each of the seven cylinder banks is cooled by a separate unit. Each unit

has four outlets, one for each cylinder of its bank, and each cylinder has two tight-fitting side plates. Top plates almost completely enclose the cooling system.

BLOWER CASE SECTION

The BLOWER CASE is attached to the rear of the crankcase by the outer of two concentric rings of studs in the front of the blower case. The hydraulic coupling support is secured to the inner ring of studs.

The hydraulic coupling compartment houses the impeller drive which consists of the hydraulic spring drive gear, two high-ratio and two low-ratio hydraulic couplings, and the impeller drive gear. The drive gear is splined to the front end of the impeller shaft. Figure 90 is an exploded view of the hydraulic coupling.

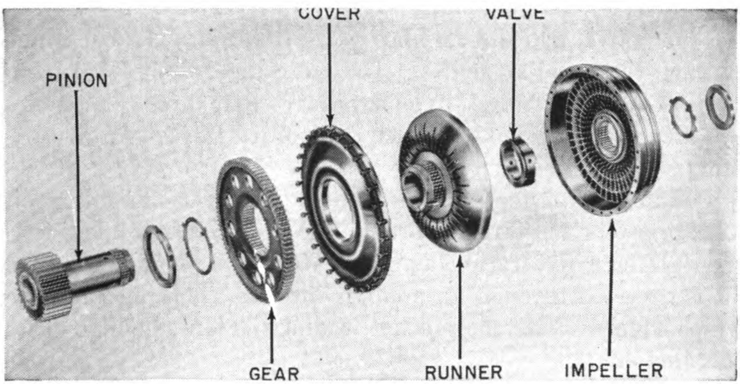


Figure 90.—Exploded view of hydraulic coupling.

The compartment is vented to the accessory drive case by two external breather lines equipped with oil tank vent connections. Three baffle screens, which line the bottom of the hydraulic coupling compartment, act as air separators for the coupling oil so that the oil drains more readily to the sump.

Fourteen bosses, grouped in pairs by the outlet ports, are integrally forged on the outside diameter of the case. Each boss has two inserts. The machined faces of these bosses

provide the pads to which the engine mounting brackets are secured.

The impeller compartment, located to the rear of the blower case web, houses the diffuser and the impeller.

The HYDRAULIC COUPLING SUPPORT secures the front ends of the hydraulic coupling shafts, and supports an oil manifold, an oil pump, and an oil check valve. Drilled passages in the support conduct oil from the high-pressure oil passage in the upper right of the blower case to the hydraulic coupling shafts for lubrication of the hydraulic coupling bearing surfaces. A spring-loaded oil pressure reducing valve, screwed into the blower case, reduces the pressure of the oil diverted to the support.

The hydraulic coupling OIL MANIFOLD is a brazed assembly of curved pipes and circular brackets attached to the front of the hydraulic coupling support. It is connected to the high-ratio and low-ratio coupling oil passages from the hydraulic coupling selector valve, and directs high-pressure oil into the couplings through the coupling shafts. The outer pipe receives oil from the low-ratio coupling oil inlet bracket and directs it to the top and bottom brackets which feed oil to the low-ratio coupling shafts.

The inner pipe receives oil from the high-ratio coupling oil inlet brackets and directs part of it to the bracket which feeds the right side high-ratio coupling shaft. The remainder of the oil is diverted through an adapter into the short middle pipe which connects with the bracket feeding the left side high-ratio coupling shaft.

The middle pipe increases the distance the oil must travel from the inlet bracket to the bracket feeding the left side high-ratio coupling shaft. This makes the oil-travel distance from the inlet bracket to the high-ratio coupling shaft approximately the same for both sides.

The hydraulic coupling support OIL PUMP drive gear is driven by the lower rear cam reduction gear. The front and rear chambers of the pump scavenge oil from the hydraulic coupling compartment. In addition, the pump is the terminus of the crankcase scavenge line. Oil discharged by the pump is

carried by an external line from the blower case to the rear oil pump outlet.

In the hydraulic coupling support CHECK VALVE, the bronze flapper hinged to the front of the support is a check valve which opens to permit oil to flow from the rear to the front section of the coupling compartment. The flapper is gravity-closed to prevent free crankcase oil from flowing back into the rear section of the coupling compartment when the plane is in a climb.

In the HYDRAULIC SPRING DRIVE GEAR, the spider is housed within the gear and retaining plates, and is splined to the accessory drive shaft coupling. The retaining plates are secured to each end of the gear by bolts which pass through the holes in the gear web. Button-seated springs reduce shock loading as they transmit rotational movement from the spider legs to the spokes of the gear web. The chambers between the spider legs and the gear spokes are filled with high-pressure oil which is admitted by check valves in the spider hub. This dampens torsional vibration.

Each of the four HYDRAULIC COUPLING SHAFTS is stationary. Each is supported at the ends by flanged bushings in the web of the blower case. The front end of each coupling shaft is secured in the coupling support by a lockscrew. The two low-ratio couplings are supported by the top and bottom coupling shafts, and the two high-ratio couplings are supported by the left and right coupling shafts.

The hydraulic spring drive gear drives the four coupling pinions. Each of the four hydraulic coupling impellers is splined to the rear end of its pinion shaft. Each of the four hydraulic coupling runners, mounted between the hydraulic coupling impeller and cover, is equipped with a steel-backed bronze bearing and turns on the shaft of the pinion. The hydraulic coupling is secured to the impeller casing.

The hydraulic coupling gear is splined to the front end of the runner. When the runner of each coupling is hydraulically engaged by its impeller, the coupling gear drives the supercharger impeller drive gear at a speed governed by the volume of oil in the coupling.

The hydraulic coupling operates in the following manner:

A sleeve-type valve with leaded silver bearing surfaces on the outside diameter and front face is installed on the shaft of each low-ratio coupling pinion between the impeller and runner. Bronze friction ring segments which contact the bore of the runner are installed in the ring groove in the outside diameter of each valve. Pins in the bottom of the groove prevent the ring segments from turning with respect to the valve. Pins in the hub of the impeller engage slots in the rear face of the valve, thereby limiting movement of the valve with respect to the impeller.

When the speed of the impeller is greater than that of the runner, the valve turns with the impeller, causing its oil holes to align with the oil holes in the pinion shaft. Under this condition, oil flows from the shaft into the coupling. The low-ratio runners, which are hydraulically engaged by the low-ratio impellers, drive the supercharger impeller drive gear at the desired low-ratio speed.

When the high-pressure oil is directed by the selector valve to the high-ratio couplings, the high-ratio runners (hydraulically engaged by the high-ratio impellers) drive the supercharger impeller drive gear at the desired high-ratio speed. This gear drives the low-ratio runners faster than the low-ratio impellers.

Friction between the low-ratio coupling valve and the runner causes the valve to turn on the shaft of the pinion in the direction of the coupling rotation. When the valve turns, its oil holes move out of alignment with the oil holes in the shaft of the pinion, thereby shutting off any remaining flow of high-pressure oil into the low-ratio coupling. This prevents low-ratio coupling operation from interfering with high-ratio coupling operation.

When high-pressure oil is cut off from the high-ratio couplings, the speed of the low-ratio runners becomes less than the speed of the low-ratio impellers. The friction between the low-ratio coupling valve and the runner then causes the valve to turn in a direction opposite that of

coupling rotation. When the valve turns, the oil holes in the valve line up with those in the shaft, and oil again enters the low-ratio couplings.

The SUPERCHARGER IMPELLER DRIVE GEAR is splined to the front end of the impeller shaft and secured by a spanner nut. This gear meshes with the four hydraulic coupling gears. The impeller shaft is internally supported on its two steel-backed bronze bearings by the accessory drive shaft.

The impeller drive gear front spacer, the thrust spacer, and the impeller shaft front ring carrier are splined to the impeller shaft between the drive gear and the impeller. The impeller shaft thrust plate, with leaded silver bearing surfaces on its front and rear faces, transmits impeller shaft thrust to the blower case. The blower case liner, the thrust plate, and the dural thrust plate oil baffle are secured to the inserts in the hub of the blower case.

The oil seal rings in the grooves of the impeller shaft front ring carrier bear against the liner in the bore of the blower case. The space between the two front and three rear rings in the carrier is vented by two elbow breathers in the web of the blower case just above the liner flange. This is to prevent excess seepage of oil into the induction system.

The impeller is splined to the impeller shaft. The inducer, which functions as a supplementary impeller, has integral vanes enclosed in an integral hoop. It is splined to the impeller shaft behind the impeller so that its vanes blend with those of the impeller. The impeller and inducer are shrunk onto the impeller shaft to form a semipermanent, dynamically balanced assembly.

The fuel slinger is splined to the impeller shaft and is seated against the rear end of the inducer. Fuel is transmitted from the slinger to the impeller vanes by drilled passages in the inducer and the impeller which connect with the holes in the front face of the slinger.

The DIFFUSER is attached to the web of the blower case and directs the fuel-air mixture from the impeller to the annulus in the rim of the blower case which has seven outlet ports.

Attached to each of the seven blower case outlet ports is a

sectional INTAKE MANIFOLD which carries the fuel and air mixture to a bank of four cylinders. Each of the four pipe sections of each manifold is coupled to its adjacent section by a clamped hose and secured by an integral flanged outlet to the inlet port of the cylinder which it serves.

The three bottom intake manifolds serve the No. 3, No. 4, and No. 5 cylinder banks, and are provided with automatic drain valves for discharging any excess fuel or oil which may accumulate while the engine is idle or being started.

To provide a PRIMING SYSTEM, a primer line is clamped to each of the three top intake manifolds which serve the cylinders in the No. 7, No. 1, and No. 2 banks. The cone ends of the primer-line tubings are connected to jet tees and elbows screwed into the intake manifold flange bosses adjacent to the inlet ports of the cylinders. The rear ends of the three primer lines are connected by union nipples to the distributor outlets. The supercharger collector rim is primed from the distributor which is attached to the blower case. The distributor inlet port is connected to the primer line from the electric primer on the carburetor.

BLOWER CASE SECTION, R–4360–18 AND R–4360–35 ENGINES

The BLOWER CASE on the models R–4360–18 and R–4360–35 engines is also attached to the rear of the crankcase and has the impeller intermediate drive support secured to it.

The impeller intermediate drive compartment houses the impeller drive which consists of the hydraulic spring drive gears, two impeller intermediate drive gears, and the impeller drive gear. The drive gear is splined to the front end of the impeller shaft. This compartment is vented by two large external breathers with brass screened ports attached to the upper sides of the case. The breathers are connected by cored passages to recesses in the web of the blower case.

Around the outside of the case and between the outlet ports are seven pairs of bosses to which the engine mounting brackets are secured.

The impeller compartment, to the rear of the blower case web, houses the diffuser and the impeller.

The IMPELLER INTERMEDIATE DRIVE SUPPORT secures the front ends of the impeller intermediate drive gear shafts and supports an oil pump and an oil check valve. Drilled passages in the support conduct oil to the impeller intermediate drive shafts for lubrication of the gears. A spring-loaded oil pressure reducing valve, screwed into the blower case, reduces the pressure of the oil which is diverted to the support from the high-pressure oil passage in the upper part of the blower case.

The blower case OIL PUMP drive gear is driven by the lower rear cam reduction gear. The front and rear chambers of the pump scavenge oil from the impeller drive compartment. The oil discharged by the pump and the oil in the adjoining rear end of the crankcase scavenge line is carried by an external line from the blower case to the rear oil pump outlet.

The blower case CHECK VALVE is a bronze flapper hinged to the front of the support which opens to permit oil to flow from the rear to the front section of the intermediate drive compartment. The flapper is gravity closed to prevent free crankcase oil from flowing into the rear section of the compartment when the engine is in climb attitude.

The HYDRAULIC SPRING DRIVE GEAR drives the impeller intermediate drive gears. A spider is housed within the gear and retaining plates, and is splined to the accessory drive shaft coupling. The retaining plates are secured to each end of the gear. Button-seated springs reduce shock loading as they transmit rotational movement from the spider legs to the spokes of the gear web. The chambers between the spider legs and the gear spokes are filled with high-pressure oil admitted by check valves in the spider hub. This oil dampens torsional vibration.

Each IMPELLER INTERMEDIATE DRIVE SHAFT is supported at its front end by the impeller intermediate drive support, and at its rear end by a flanged bushing in the web of the blower case. Each shaft, in turn, supports an impeller intermediate drive consisting of two integral spur gears. The smaller of the two gears meshes with the impeller drive gear.

INTAKE MANIFOLDS, R-4360-35 AND R-4360-35A ENGINES

Attached to each of the seven blower case outlet ports is a sectional intake manifold which carries the fuel and air mixture to a bank of four cylinders. Each of the four pipe sections of each manifold is coupled to its adjacent section by a steel-shielded rubber diaphragm-type coupling, and is secured by an integral flanged outlet to the inlet port of the cylinder. The A4 and A5 intake manifold pipe sections are each provided with a float-type fuel drain valve for discharging any excess fuel or oil which may accumulate while the engine is idle or being started.

PRIMING SYSTEM, R-4360-35 AND R-4360-35A ENGINES

The supercharger collector rim is primed by a two-point primer system incorporating discharge nozzles in the blower case to the left of No. 7 and No. 2 bank intake manifold blower connections. The left and right primer lines are clamped to the blower case, and are connected to the nozzles by tubing fittings. The two primer lines are connected by union nipples to the two distributor outlets. The distributor is attached to the blower case and receives fuel from the electric primer on the carburetor.

ACCESSORY DRIVE CASE SECTION

The ACCESSORY DRIVE CASE, which is attached to the studs in the rear face of the blower case, supports the main sump assembly, the rear oil pump, the rear accessories, and the rear accessory drives. A cover is attached to the rear of the accessory drive case.

An oil pressure reducing valve in the bottom of the case reduces the pressure of the accessory drive lubricating oil before it is directed to the various accessory drives by the oil distributor secured to the rear face of the case.

The accessory drive case is vented by two breather outlets. It has a flange for mounting an injection-type down-draft carburetor.

The POWER TAKE-OFF for the model R-4360-18 engine is coaxial with the crankshaft, and is located on the accessory

case. This unit is driven through a train of gears at a ratio of 3:1 crankshaft speed.

Fuel is conducted into the FUEL FEED VALVE housing through a passage in the accessory drive case which connects with the external fuel feed pipe from the carburetor. When the pressure of the fuel exerted outwardly against the valve diaphragm is less than the force which is exerted inwardly, the valve remains seated against the discharge end of the valve housing, thereby shutting off the fuel flow. When the fuel pressure exceeds the force of the spring, the diaphragm lifts the valve off its seat, and fuel flows to the fuel slinger. An exploded view of the fuel feed valve is illustrated in figure 91.

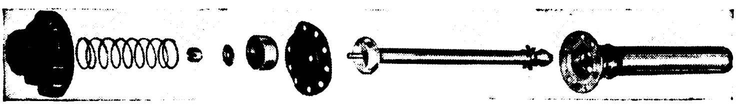


Figure 91.—Exploded view of fuel feed valve.

The front end of the ACCESSORY DRIVE SHAFT coupling, and the grooved bearing journal at the rear end of the shaft, are supported by steel-backed bronze bearings in the bore of the accessory drive case. The rear accessory drive gear, which is splined to the accessory drive shaft, drives the fuel pump intermediate drive, the vacuum pump intermediate drive, the generator drives, the rear oil pump intermediate drive, and the magneto pump intermediate drive.

The MAIN SUMP, which collects drain oil from the rear crankcase, the blower case, and the accessory drive case sections, is mounted on a pad at the bottom of the accessory drive case. This pump houses an oil strainer (fig. 92), an oil screen assembly, and the supercharger fuel drain valve.

The oil screen assembly consists of two concentric, cylindrical oil screens which are installed in the center chamber of the sump. This chamber is continuous with a cavity in the sump mounting pad into which the oil return check valve is screwed. The oil screens are retained within the sump by a cover and oil drain plug assembly.

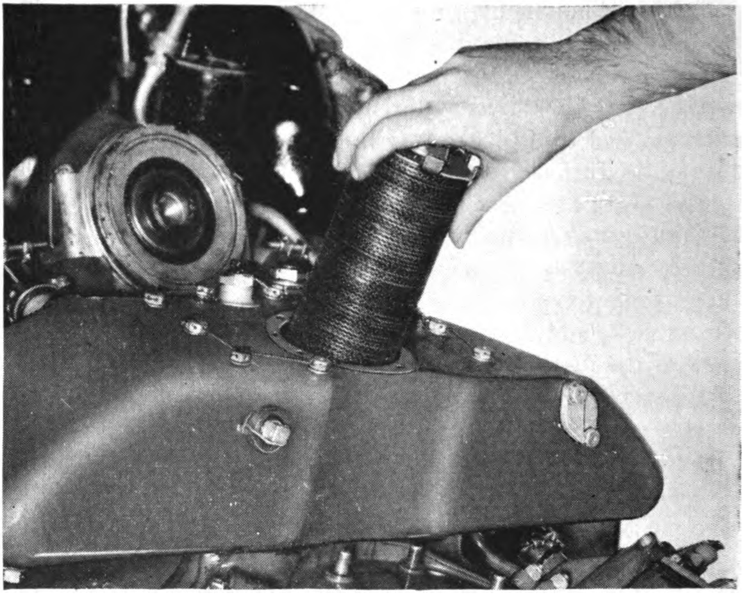


Figure 92.—Removing oil strainer.

The SUPERCHARGER FUEL DRAIN VALVE is contained within, but is functionally independent of, the main sump. This valve drains excess fuel which may accumulate in the intake duct and the diffuser when the engine is being started. The valve closes automatically after the engine starts.

The FUEL PUMP and MAGNETO PUMP INTERMEDIATE DRIVES are supported in brackets secured to studs in the upper right and left sides, respectively, of the accessory drive case web. The inner intermediate drive gears mesh with, and are driven by, the rear accessory drive.

The inner intermediate drive gears are splined to the shafts of the outer intermediate drive gears which mesh with their pertinent drive gear. The fuel pump and magneto pump drive gears are splined to the inner ends of the fuel pump and magneto pump drive shafts.

The drive shafts are supported at their outer and inner ends by bronze bearings. Each shaft has an integral spiral gear

which drives a tachometer drive shaft. The internal splines in the outer ends of the drive shafts drive the fuel pump and the magneto pressurizing pump.

The two TACHOMETER DRIVE GEARS—one in the left side and one in the right side of the accessory drive case—are driven by the spiral gears of the fuel pump and magneto pump drive shafts.

The STARTER GEAR meshes with the rear accessory drive gear, and is splined to the shaft of the starter jaw. The three-tooth starter jaw, which provides for starter engagement, is held in a support secured in the right side of the accessory drive case.

The bottom GENERATOR DRIVE GEAR is held on a bronze bearing in a support secured in the bottom of the accessory drive case, while the side generator drive gears are held in bearingless supports secured in the left side and lower right side of the accessory drive case. The gears are driven by the rear accessory drive gear. The internal splines in the outer end of each gear may be used to drive a generator or vacuum pump single drive.

The VACUUM PUMP SINGLE DRIVE GEARING is housed within a gear box which may be mounted on either of the three generator drive pads. The vacuum pump single drive gear is driven by the smaller gears of three compound pinions. The larger gears of the pinions are driven by the vacuum pump single intermediate drive adapter gear. The outer end of this gear rotates in a bearing pinned into the bore of the drive gear. The inner end of the intermediate adapter gear may be splined into and driven by either of the three generator drive gears.

The VACUUM PUMP THREE-WAY ADAPTER is mounted on the lower right side of the accessory drive case. It houses and supports side and center drive gears. The two side vacuum pump drive gears are driven by the center vacuum pump drive gear. This latter drive gear is supported by a bronze bearing in the adapter. The outer end of the vacuum pump drive bell gear is splined into the center vacuum pump drive gear.

Each engine equipped with a vacuum pump three-way adapter incorporates a vacuum pump intermediate drive gear in place of the generator drive gear in the lower right side of

the accessory drive case. The bevel gear at the inner end of the shaft is driven by the rear accessory drive gear. The spur gear at the outer end of the shaft drives the vacuum pump drive bell gear.

The REAR OIL PUMP INTERMEDIATE DRIVE BEVEL GEAR is driven by the accessory drive gear. It is held in a support secured in the lower left side of the accessory case. The rear oil pump intermediate drive spur gear is splined to the outer end of the bevel gear and drives the rear oil pump drive gears.

The REAR OIL PUMP has a single-chamber pressure section and a two-chamber scavenge section. It is mounted on the lower left side of the accessory drive case. A pressure relief valve and an oil screen bypass valve are screwed into the pump body. The pump has square mounting pads for the oil inlet and outlet connections, a pad above the outlet for the connection of the oil line from the blower case, and a fitting for the connection of the oil line from the rear rocker box sump. Figure 93 shows a sectional view of the rear oil pump.

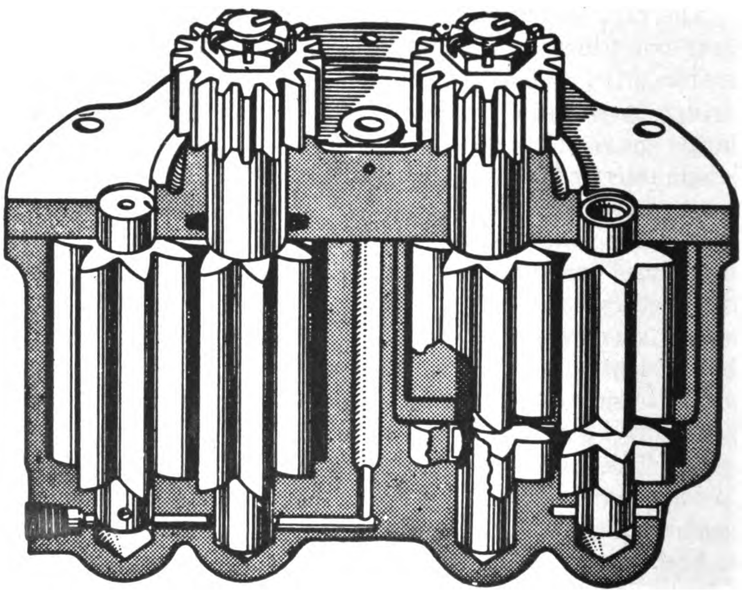


Figure 93.—Sectional view of rear oil pump.

The radio-shielded ignition system consists of seven separate Scintilla D4RN–2 magneto units—one complete magneto unit for the four cylinders in each of the seven banks. Each magneto unit consists of a magneto to which is attached a spark plug lead and distributor block harness. Each lead harness directs the high-tension impulses generated by its magneto to the eight spark plugs in the bank of four cylinders just behind the magneto.

Each of the seven magnetos is flange-mounted on one of the pads radiating from the magneto drive case, and is of the four-pole rotating magnet type. Each magneto has a compensated cam with two tracks of four lobes each, two sets of breaker points, and a distributor rotor with four jump-gap pickup electrodes and two distributing electrodes. With the exception of the cams which are timed to the front cylinders of the corresponding banks, all seven magneto units are identical and interchangeable. A coupling on the engine end of each magneto shaft is splined into the outer end of the corresponding magneto drive shaft in the magneto drive case. A ratchet ring between the coupling and the magneto shaft provides a vernier adjustment of the shaft for timing the magneto to the engine.

The distributor block end of each of the seven high-tension spark plug lead harnesses is attached to the side of the magneto which opens into the distributor rotor compartment. Each distributor block carries eight electrodes, one for each of the eight spark plugs in the bank. The leads from the electrodes to the spark plugs are housed in a metallic conduit filled with moisture-proof sealing compound. The rear lead elbow of each harness is provided with an integral blast tube.

The GROUND WIRE MANIFOLD is the only common connection between the seven magneto units. By means of a selector-type magneto switch in the instrument panel, the pilot can selectively check either the right or left spark plugs fired by any one of the seven magnetos. Three booster coils, connected to the ground wires from No. 7, No. 1, and No. 2 magnetos, increase the high-tension voltage for starting the engine at speeds below the coming-in speed of the magnetos.

The magnetos are pressurized to prevent flashover at high altitudes. The rotary vane pump which pressurizes the magnetos is mounted on the upper left side of the accessory drive case and is driven by the magneto pump drive shaft. The airtight conduits of the ground wire harness carry the pressurized air into the magneto through holes in the ground wire connectors. By permitting a predetermined amount of air leakage, the altitude valve in each magneto housing maintains a delicate balance between the air pressure for flashover prevention and the air flow for magneto ventilation.

A schematic view of the electrical and magnetic circuits is shown in figure 94.

MODELS R-4360-2 AND R-4360-4 POWER CONTROL

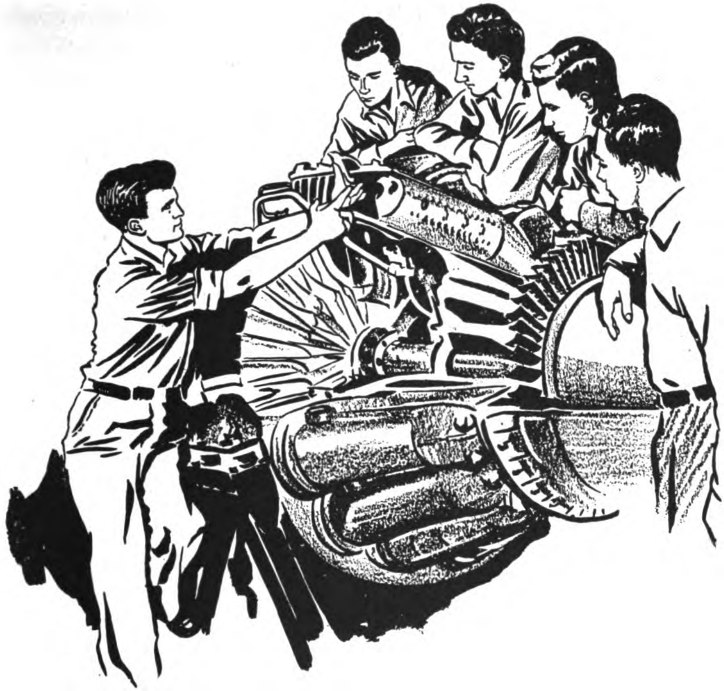
The Eclipse Automatic Power Control Unit is attached to a pad on the left side of the accessory drive case. This unit is essentially a manifold pressure regulator at its present stage of development. It requires only one cockpit control, and operates and correlates the carburetor throttle with the supercharger impeller drive coupling selector valve.

The automatic power control (as an automatic manifold pressure regulator unit) maintains constant manifold pressure regardless of change in altitude. An aeroid bellows arrangement regulates the throttle in conjunction with the supercharger impeller speed as required.

QUIZ

1. Give a brief description of the Pratt & Whitney major R-4360 engine.
2. What parts and assemblies are supported by the propeller shaft case?
3. How many valve tappet guides are there?
4. Where is the magneto drive case mounted?
5. What is the function of the spark advance gear?
6. How are the cams driven, and at what speed?
7. How is the crankshaft constructed? How many crankpins support bearing journals does it have?

8. How are the knuckle pins for this engine classified?
9. Of what material is the seat of the exhaust valve composed?
10. What banks of cylinders do the three bottom intake manifolds serve?
11. How are the tachometer drive gears driven?
12. What type of magnetos are used on this engine? How many?
13. Why are the magnetos pressurized?
14. Are the exhaust valves and inlet valves of the same size? Which is larger if they are not of the same size?



CHAPTER 10

THE TURBO-JET ENGINE

You may have wondered why the subject of jet propulsion has become so important to modern aviation in view of the remarkable advancement in propeller-driven aircraft performance in recent years. It is likely that the development has come about for the same reason that most important technical advances have taken place—existing techniques have been unable to meet new aircraft performance requirements.

Builders of propeller-driven aircraft, ever striving for better performance at higher speeds and higher altitudes, were handicapped in their efforts by the lack of compact, lightweight, high-powered engines. Although the latest and best reciprocating engines developed more than 2,000 hp. with a specific fuel consumption of 0.5 pounds per b.hp., and weighed approxi-

mately one pound per b.hp., the demand remained for still more powerful units of less weight and reduced frontal area.

How was this demand to be met? The development of existing multicylinder reciprocating engines might be continued, or an entirely different type of engine might be sought. The first alternative, however, had become excessively complicated in design and limited in its results. The second method was found to be easier and to offer greater potential advantages.

The idea of jet propulsion was not new by any means. The "equal and opposite" effect of force and reaction was, in fact, known to the ancients and embodied in physical laws by Sir Isaac Newton nearly 300 years ago.

Modern metallurgical developments have made possible the construction of units that will withstand the high temperatures and pressures found in jet engines. Actually, turbo-jet units have been easier to design and quicker to produce than the conventional engine. Successful bench tests have been made on some engines only six months off the designers' boards, while even under the impetus of war it required from 4 to 5 years to bring a large reciprocating engine to the fully operational stage.

A turbo-jet unit, quite naturally, has its own peculiar problems. It does not, however, suffer the numerous limitations of the reciprocating powerplant. In operation, it has virtually no out-of-balance forces, and consequently very little vibration. Frictional surfaces are limited to a few ball, or roller, bearings which can be furnished adequate lubrication without the losses involved in oiling the sliding pistons of the conventional engine. Weight and space occupied are no more than one-third to one-half of that required for equivalent reciprocating engines.

METHODS OF JET PROPULSION

All aircraft propulsion is accomplished by displacing a mass of air to the rear. The 12- to 16-foot propeller on a conventional reciprocating engine displaces the mass at a relatively low velocity. A jet unit projects a column of air about one

foot in diameter to the rear at an extremely high velocity—actually faster than the speed of sound. In both cases, the resulting effect is to propel the aircraft in the forward direction.

Jet propulsion units may be conveniently grouped into the following four main classes:

Rockets—jet propulsion systems not utilizing atmospheric air.
Ram jet—the continuous thermal duct or athodyd.
Aeropulse (or pulse jet)—the intermittent impulse duct.
Turbo-jet—the continuous turbine-compressor unit.

A number of subdivisions and variations can, of course, be made to these four main classes.

Although correctly included as a form of jet propulsion, the ROCKET differs essentially from the other thermal jet systems since it must carry both fuel and the oxygen necessary for combustion. This is a disadvantage for atmospheric travel, but makes it the only means at present conceivable for flight above the atmospheric belt. The rocket is, however, a true jet reaction unit, and a brief examination of its functions will serve to clarify the reaction principle on which all thermal jet units operate.

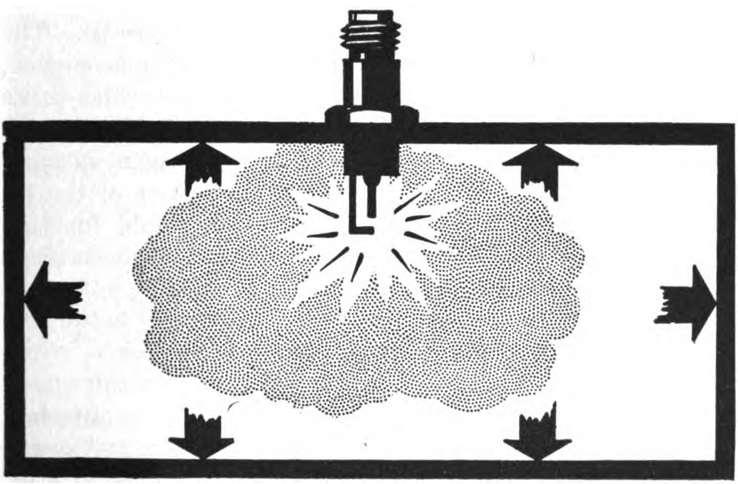


Figure 95.—Combustion in a closed vessel.

If a hydrocarbon fuel and oxygen are ignited in a closed vessel, as illustrated in figure 95, the latent heat of the fuel is released and there is a rapid expansion of the resulting gases. Because of the fixed volume of the vessel, a rise in temperature will take place which will be uniformly distributed in every direction. Since the force of the pressure is balanced, there will be no tendency for the vessel to move.

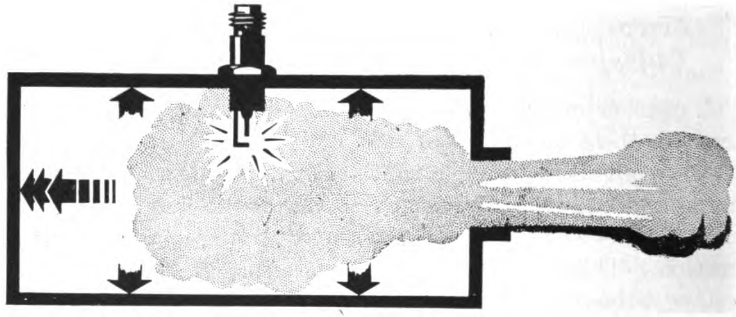


Figure 96.—Principle of jet propulsion.

On the other hand, when combustion takes place in a vessel with an aperture at one end, the expanding gases will rush out of the nozzle at a high velocity, as shown in figure 96. The internal pressure at the nozzle end of the vessel is thus relieved, leaving an unbalanced pressure at the other end which tends to propel the vessel in the direction opposite to that of the issuing jet. Obviously, it is dependent solely upon internal conditions, and there is no suggestion whatsoever of the jet "pushing against" external air. In fact, it would function most efficiently in a complete vacuum. This is the basic principle upon which all jets operate.

THE ATHODYD

Suppose that a plain cylinder with open ends is attached longitudinally to an aircraft flying at high speed. Air will enter at the forward end of the duct and will emerge as a jet at the rear. Nothing will be added to the force of the flow

through the duct and, in fact, some energy will be lost because of skin friction and disturbance of flow at the entrance and exit.

However, if some means of adding heat to the air as it passes through the duct is employed, the air will be expanded and the velocity of the jet from the tail will be increased. Figure 97 shows diagrammatically a cylindrical duct heated externally by burning oil sprays. Since there is no forward surface against which the reaction to the jet can apply, the aircraft will not benefit from the unbalanced forces thus created.

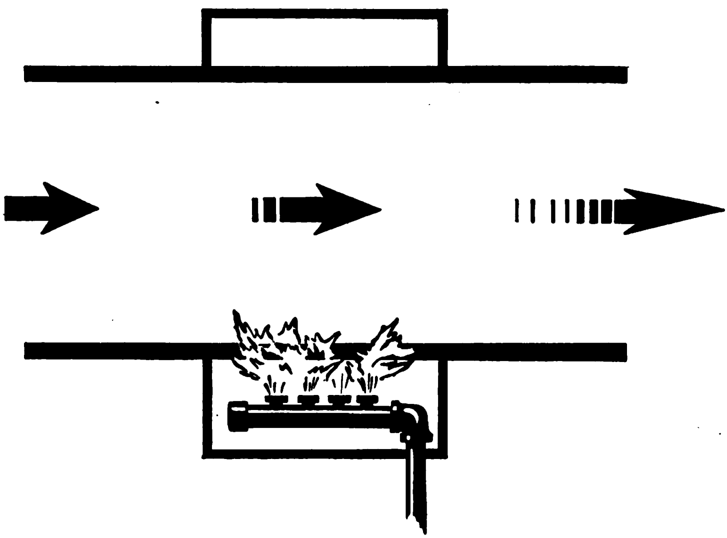


Figure 97.—Thermal duct with heat added externally to accelerate the air flow.

The amount of heat that can be added is largely dependent upon the pressure of the air being treated. A simple method of raising the pressure is to pass the air through a DIVERGENT entry nozzle, as shown in figure 98. An entry nozzle of this shape decreases the velocity of the air and, hence, increases the pressure. More heat can then be added to the air by burning more fuel and thus increasing the velocity of the issuing jet.

A further advantage can be obtained by forming the exit of the duct as a CONVERGENT nozzle. This device increases the

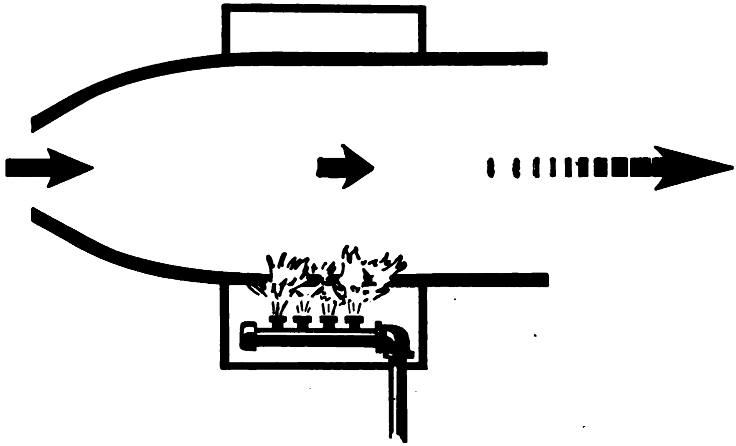


Figure 98.—A divergent entry nozzle.

velocity of the jet of air while lowering its unit pressure. Figure 99 illustrates the most elementary type of jet propulsion unit. Air compression depends solely upon "ram" effect; only a limited amount of heat can be added, and considerable heat is lost by radiation. Consequently, the efficiency of this type unit is too low for it to be of practical use for the propulsion of aircraft.

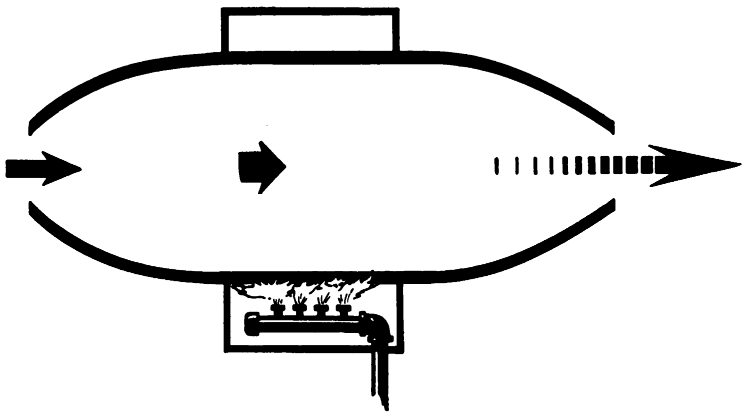


Figure 99.—A convergent discharge nozzle increases the velocity of the issuing jet.

The next obvious step is to improve the method of adding heat. This can best be accomplished through internal combustion. Figure 100 shows a divergent-convergent duct into which fuel is injected and burned so that the heat is released directly to the air stream. A slight advantage is obtained since, instead of being lost to atmosphere, the products of combustion are entrained with the air flow and add to the mass of the propulsive jet. It is, however, attended by an exorbitant fuel consumption, and is incapable of providing initial power for take-off. Nevertheless, some application may be found for this type unit by using rocket-assisted take-off or a catapult launch. This simple "continuous thermal duct" unit is a RAM JET, sometimes termed an athodyd.

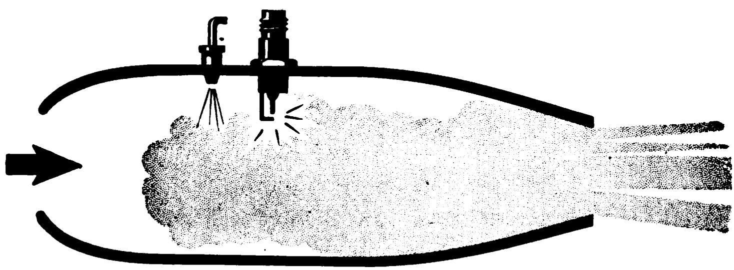


Figure 100.—Internal combustion in a ram jet.

THE PULSE JET

Combustion pressure is further improved in the "intermittent impulse" duct-type jet propulsion unit. This unit, known as the aeropulse or PULSE JET, is shown in figure 101. Improved compression is accomplished in the pulse jet by sacrificing the principle of continuous power generation.

The pulse jet is a tube fitted with a series of non-return admission valves and fuel-injection nozzles at the forward end. As it travels through the air, pressure on the nose opens the valves and rams air into the duct to mix with the fuel and form a combustible mixture. When the fuel-air mixture is heated, there is a rapid expansion of the gases and a rise in pressure which closes the valves. The violent ejection of the

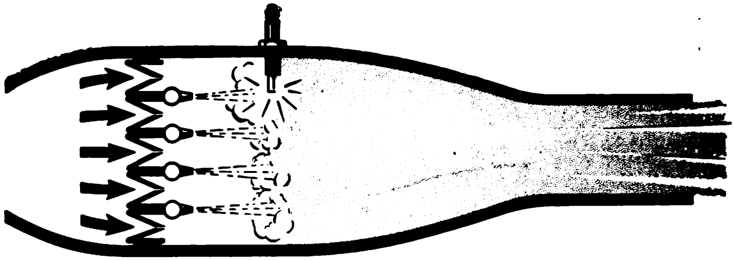


Figure 101.—The aeropulse, or pulse jet, as employed on the German buzz bomb.

gases creates a relatively low pressure area inside the duct which allows the flat spring valves to admit a fresh charge of air, and the cycle is repeated.

The frequency of the cycle depends upon the construction of the duct, and may be relatively high. A propulsion unit of this type, fitted to the German V–1 flying bomb, had a frequency of about 2,800 cycles per minute.

MECHANICAL AIR COMPRESSION

For the jet propulsion unit to compete favorably with the conventional reciprocating-type internal-combustion engine, it was necessary to mechanize the compression of the air. Experiments with reciprocating compressors have been made, but the more appropriate rotary compressor is used in all turbo-jet engines in current production. Both radial and axial flow types are used.

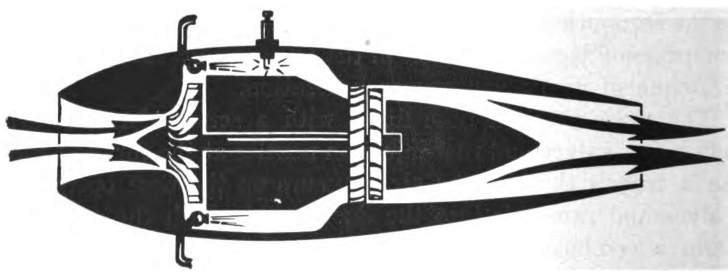


Figure 102.—Simple compression and combustion gas turbine engine.

A simple rotary unit uses a combustion gas turbine mounted on a common shaft with the compressor. The turbine is designed to extract sufficient energy from the combustion gas stream to drive the compressor and ensure continuous operation. Figure 102 shows diagrammatically this turbine-compressor combination which is the basis of the turbo-jet engine.

A COMPARISON WITH FOUR-STROKE ENGINES

You are undoubtedly acquainted with the conventional four-stroke cycle, reciprocating engine used in automobiles, and with its cycle of operation—induction, compression, expansion, and exhaust.

All four of the above functions take place in regular sequence in each cylinder of the engine. The piston descends and the mixture of air and gasoline enters the cylinder through the opened inlet valve; the inlet valve closes, and the piston ascends to compress the mixture which is then ignited by an electric spark. The expansion resulting from the ensuing combustion forces the piston downward. This is the sole power stroke. Finally, the piston once more ascends to expel the burned gases via the exhaust valve.

In an engine operating at a crankshaft speed of 3,000 r.p.m., each stroke is completed in $\frac{1}{100}$ second and a complete cycle of operation in $\frac{1}{25}$ second. At this r.p.m., each piston is accelerated, decelerated, and its direction of motion reversed 6,000 times per minute. As the power stroke per piston occurs only once in every two revolutions of the crankshaft, the working energy is applied to the shaft intermittently. The frequency of application in a particular engine depends upon the number of cylinders.

Figure 103 presents a series of sketches showing a complete cycle of four strokes of a reciprocating engine, and immediately above is a sectional diagram of a gas turbine engine with a multistage axial compressor and a single-stage turbine. The positions of the two diagrams are arranged to show the corresponding functions of the two power units. In comparing the action of the two types of engines, it must be remembered that the gas turbine engine produces power continuously—

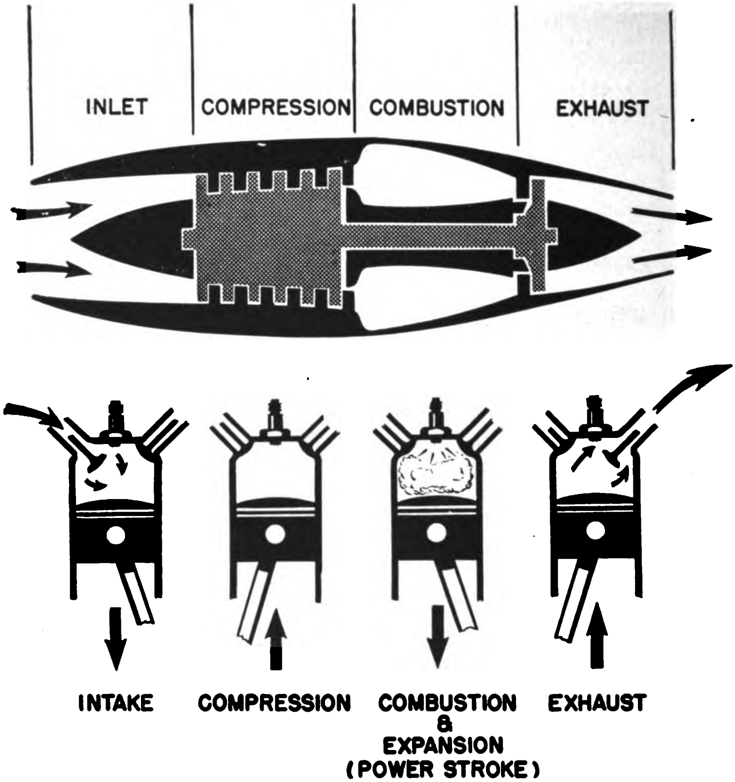


Figure 103.—A comparison of turbo-jet and reciprocating power units.

that is, there are no intermittent explosions as in a reciprocating engine.

HOW THE TURBO-JET ENGINE WORKS

A turbo-jet unit consists of five major components—an inlet duct, a rotary AIR COMPRESSOR at the front, a series of COMBUSTION CHAMBERS into which fuel is sprayed and burned continuously, a TURBINE revolving with the compressor on a common shaft, and the EXHAUST SECTION. There are no pistons, valves, or ignition apparatus (except for the starting unit).

To start the engine, a fuel valve is opened and the control timer switch is depressed. The control timer closes the starting circuit for about 30 seconds. The electric starter spins the main shaft and rotors while the ignition coils provide a high voltage to the spark plugs for ignition of the fuel-air mixture.

When combustion of the mixture begins in either of the chambers fitted with spark plugs, the flame spreads to the other chambers through connecting pipes. No warm-up period is necessary since there are no metal-to-metal sliding surfaces and few bearings to be lubricated.

On the ground, air is forced by the compressor into the combustion chambers at a pressure of approximately four atmospheres. Liquid fuel is pumped at a high pressure into the compressed air and burned continuously, somewhat in the manner of a blowtorch. In flight, the work of compressing the air is greatly assisted by the forward motion of the aircraft. Increased altitude and the consequent lower air temperature also improve the efficiency of the compression system.

Only a small portion of the total quantity of air taken aboard is used to provide the necessary fuel-air combustion ratio of about 14:1. The major portion of the air passes around the actual combustion area and combines with the combustion gases farther on in the combustion chamber. The combustion temperature of approximately 1,800° C. raises the temperature of the whole air mass to about 850° C., at which temperature it passes through the turbine.

The velocity of the air is tremendously increased because of the expansion caused by the heat. The high-velocity air passes between the guide vanes in the stator ring of the turbine. These vanes direct the flow to the appropriate angle of attack for the blades of the turbine wheel. The rapid passage of the heated mixture through the blades causes the turbine wheel to rotate at speeds from 8,000 to 16,000 r.p.m., depending on the particular engine. The mechanical energy developed here drives the compressor, which is mounted on the front end of the turbine shaft, thus forcing more air into the combustion chamber to continue the cycle.

As in the conventional engine, less fuel is required at higher altitudes. A barometric regulator automatically adjusts the

supply of fuel injected into the combustion chambers. The usual fuel is kerosene or low-grade gasoline, since the chief requisite of jet-engine fuel is a high-heat value per unit of the fuel.

COMPRESSORS

Rotary air compressors are classified in accordance with the line of air flow. The RADIAL FLOW type, often called a centrifugal flow compressor, may have one or more stages, but the AXIAL FLOW type is invariably a multistage unit. There are some few units (MIXED FLOW type) in which an initial radial stage is followed by a number of axial stages and, conversely, axial stages with a terminal radial stage.

RADIAL COMPRESSORS

The radial compressor has received many years of intensive development as an engine-driven blower for supercharging reciprocating-type aircraft engines, and its performance and reliability have been well established. Consequently, it was adopted for gas turbines. While it can satisfactorily furnish the volume of air required by a piston engine operating with a fuel-air ratio of about 15:1, it is less well suited for the turbo-jet unit which requires a total air-fuel ratio of from 60:1 to 70:1. The volume of air to be handled necessitates an impeller of large diameter and a high speed of rotation, resulting in a high linear speed at the periphery. It is not uncommon for the tip speeds of impellers to exceed the speed of sound, but in a turbo-jet unit it is most desirable to maintain a smoothly accelerating flow and to avoid surging or wave effects.

The diameter of a radial compressor is necessarily greater than an equivalent one of axial type, and thus the overall diameter of the unit is greater.

There are, however, compensating advantages when the radial compressor is compared with the axial type. It is cheaper to produce, more sturdy, can be run at higher speeds, and is less prone to icing. Furthermore, it has a wider effective operational range than the axial type, and in this respect is more suitable for use in a variable speed, variable load jet-propulsion unit.

Air enters the radial compressor casing by way of the relatively small intake eye around the hub, is picked up by the radial vanes of the rotating impeller, rapidly accelerated, and discharged from the periphery into a diffuser. This annular chamber is provided with a number of vanes forming a series of divergent passages, the function of which is to build up pressure in the air stream at the expense of velocity. The air passes from the diffuser to a discharge scroll having one or more outlets, as may be seen in figure 104.

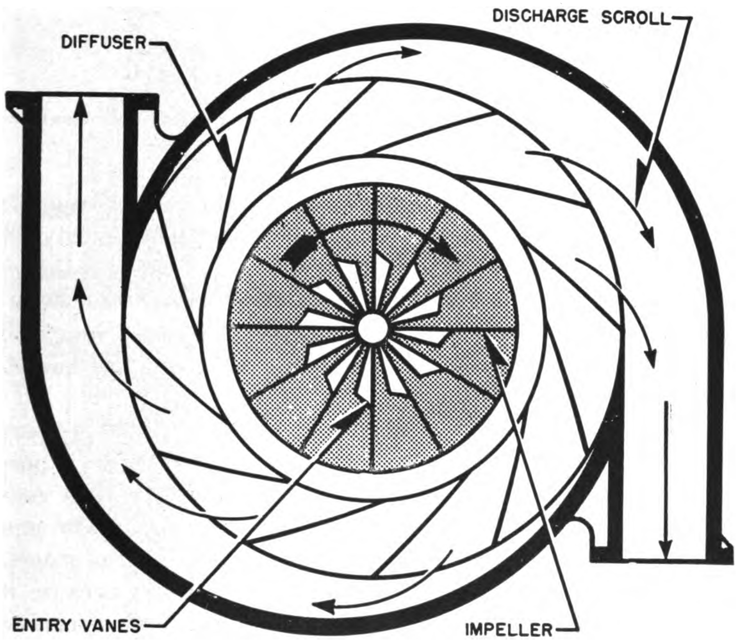


Figure 104.—Diagram of radial compressor with only two discharge outlets.

Drawings of three different types of impellers are given in figure 105. A simple single-entry "web"-type (A) has radial vanes supported on one side by a disc. The small curved vanes around the hub are "entry" vanes to facilitate the change in air flow from the axial to the radial direction and thus reduce the so-called "entry shock."

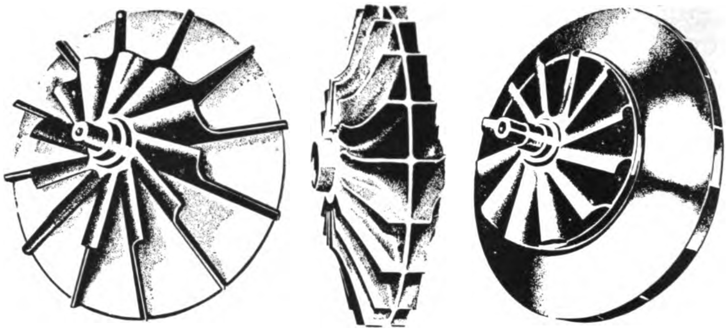


Figure 105.—Three commonly used types of impellers for radial compressors.

The double-entry type (B) is a variation of the web-impeller type, having radial vanes on each side of the single central disc. Air enters at each side and is delivered to a common collector duct. It is, in effect, two single-entry impellers arranged back-to-back. The third impeller (C) is designated the "closed" or "shrouded" type. This resembles type (A), but has an annular wall on the entry side.

It is practical to design radial compressors for a pressure ratio approaching 4:1 in a single-stage impeller, and it is possible to achieve even higher pressures. However, it is generally preferable to keep the stage ratio reasonably low and obtain the desired pressure by increasing the number of stages. This substantially increases the length of the unit because it necessitates air passages from one stage to the next, as can be seen in the diagram of a two-stage unit in figure 106. Interstage losses lower the overall efficiency.

AXIAL COMPRESSORS

Although the design and construction of axial compressors is quite different from that of the radial type, it is subject to the same laws and limitations. The line of flow is relatively more direct, but at each stage the air must be accelerated in

the direction of rotation and then channeled at the appropriate angle for the next stage.

Three stages constitute a probable minimum for an axial

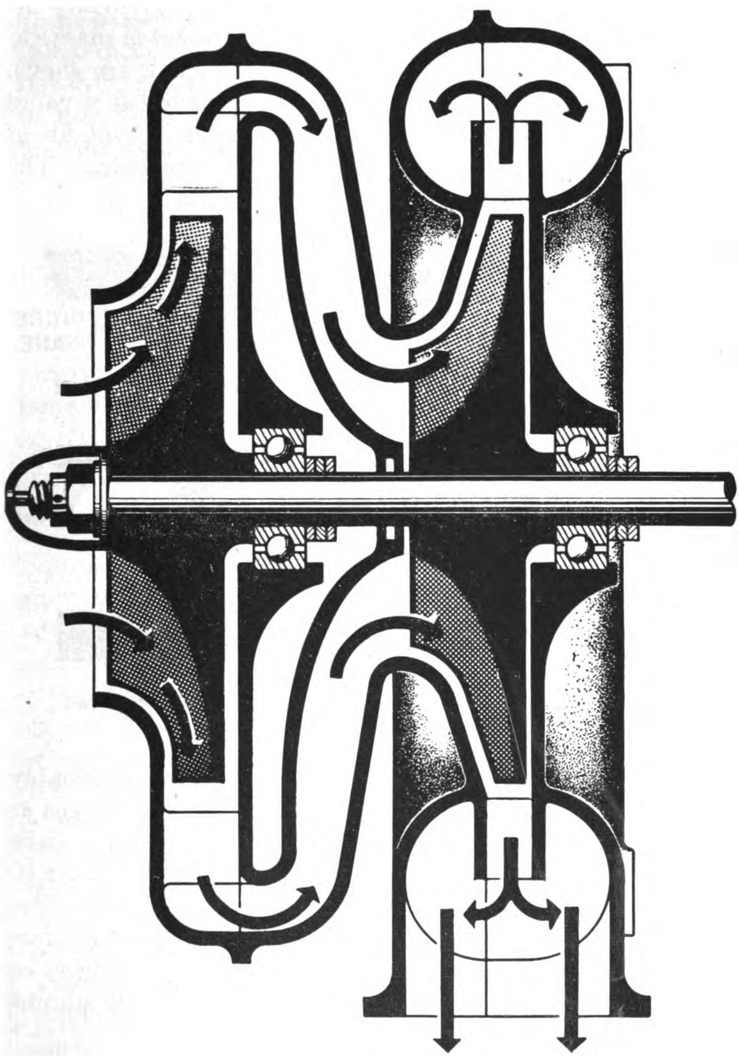


Figure 106.—Section of two-stage radial compressor.

compressor, but the practicable maximum number of stages may run much higher.

The schematic diagram in figure 107 shows the arrangement of component parts in a five-stage axial compressor. The casing is usually cylindrical, and compression is gradually increased by the use of a rotor drum which increases in diameter from entry to discharge. Eleven rows of blading are shown in this diagram, although the discharge vanes and entry vanes may be omitted in certain designs. The rotor is built up of five discs, each of which has one row of rotor blades. The compressor casing has six rows of stator blades.

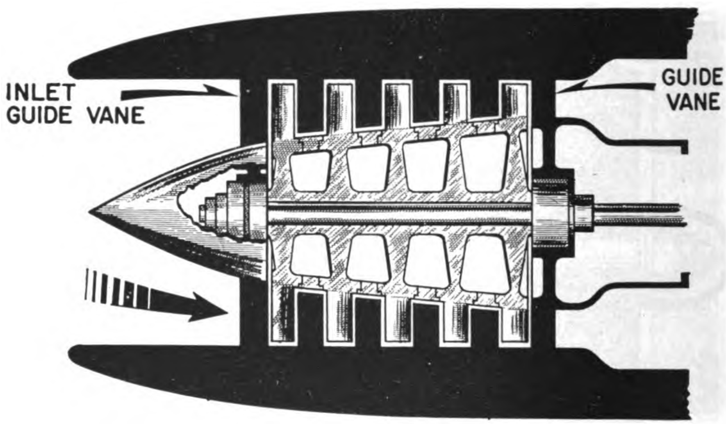


Figure 107.—Schematic diagram of a five-stage axial compressor.

Rotor discs may be of steel or light alloy, and will probably decrease in width from low-pressure to high-pressure stages as they accommodate blades of diminishing chord. Steel or light alloy blades are machined to profile from individual forgings. Methods of fixing the blades to the disc vary in different designs, but they are commonly fitted into tee or dovetail slots in the periphery of the disc and secured by pins, wedges, or screws. The number of rotor blades per disc usually diminishes stage by stage from intake to discharge.

Stator blades, which direct the air flow between stages, may also be of either steel or light alloy, and are usually assembled

in half-rings for mounting in the longitudinally divided light alloy compressor casing. They may be machined from forgings, folded from sheet material, developed from tubes, or, in the case of steel, even cambered from a single sheet.

An axial compressor with fixed blading has only a limited range of air delivery volumes. With adjustable rotor blades, however, it could be regulated to deliver any volume from zero to maximum. Such an innovation might prove to be as important as the variable pitch propeller.

Another method of regulating the output of a multistage axial compressor is to have one or more rings of rotor blades disconnectably mounted on the rotor shaft and allowed to run idly in the air stream for reduced delivery. Furthermore, one or more sets of stator blades may be disconnectably mounted in the casing and similarly allowed to rotate idly for reduced output. Disconnectable rotor and stator blade rings may be embodied in the same design.

TURBINES

In a pure turbo-jet unit, all the power delivered by the turbine is expended in driving the air compressor and the necessary auxiliary equipment. The following paragraph will furnish an idea of the power developed by an aircraft gas turbine engine.

A jet-propulsion engine will deliver approximately 50 pounds of thrust for every pound of air flowing through the unit per second. To drive a modern rotary compressor, approximately 100 horsepower is necessary for each pound of air delivered per second. It follows that in a unit developing 2,500 pounds of thrust, the turbine driving the compressor must produce about 5,000 horsepower. This estimate is revealing, as it shows an expenditure of energy equal to or greater than that of a pair of conventional reciprocating engines of high power output. It indicates why performance of a jet-propelled aircraft is so outstanding and why the rate of fuel consumption is relatively high. In short, the turbo-jet engine is a high-powered unit.

The turbine consists of a nozzle assembly and a rotating blade assembly. The hot gases from the combustion chamber

flow through the turbine nozzle assembly and are directed against the rotating blades of the turbine disc.

The rotating blade assembly (turbine rotor) is made up of a steel shaft and disc. High-temperature alloy blades are locked in grooves cut in the periphery of the disc, and the entire turbine rotor is statically and dynamically balanced. The turbine rotor and the compressor rotor are mounted on the same shaft in some units, while in others they are mounted on separate shafts which are connected during assembly.

The nozzle assembly consists of the nozzle guide vanes and the stator ring or shroud ring. The guide vanes are made up of high-temperature alloy. They are fitted into or welded to the stator ring or shroud. The turbine rotor and the nozzle assembly (fig. 108) are housed in the rear of the combustion chamber.

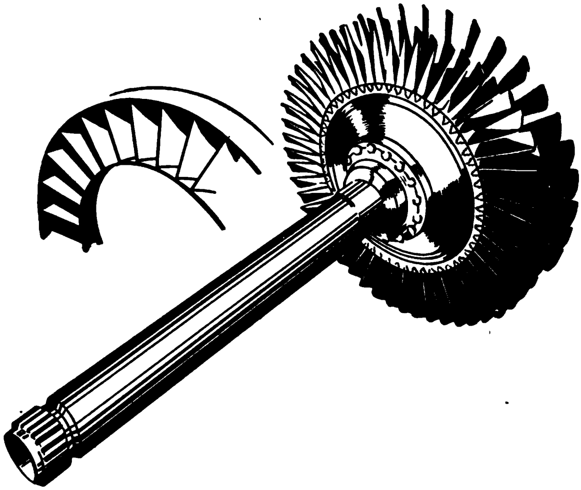


Figure 108.—Turbine nozzle and rotor.

At the present level of development, a single-stage turbine can provide all the power necessary to drive a single-stage radial compressor. It is lighter, simpler in design, easier to manufacture, and more efficient. Multistage turbines are more applicable to axial flow compressors, which operate at lower speeds of rotation.

The efficiency and performance of a turbine power unit are materially influenced by the combustion system employed. Basic requirements for a satisfactory system are a high rate of burning, minimum pressure drop, small bulk, and light weight. The system must be consistent in operation over a wide range of loads and altitudes, with no liability to flood with fuel or to suffer "combustion blow-out" ("combustion blow-out" refers to flame failure, and is primarily a problem in high-altitude operation). Starting must be easy and positive both on the ground and in the air, and combustion must be complete to avoid formation of carbon.

Entirely new problems were presented by the aircraft gas turbine. One such problem involved the release of the necessary heat values at the required rate of burning. Another was concerned with the severe limitations in respect to weight and space occupied. That these problems were overcome is confirmed by the fact that in a light tubular combustion chamber of fabricated sheet steel, which by ordinary furnace standards would be regarded as flimsy, it is possible to release more than 300,000 heat units per minute.

The majority of aircraft gas turbine engines have between 8 and 16 combustion chambers. Some designs, however, use only one annular combustion chamber. Each chamber (fig. 109) consists of an outer casing usually made of mild steel, a flame tube made of a high-grade heat-resisting alloy, and a burner nozzle. Each chamber is joined to its adjacent chamber by means of cross-over tubes. Fuel is introduced from the burner nozzle into the flame tube where it mixes with the com-

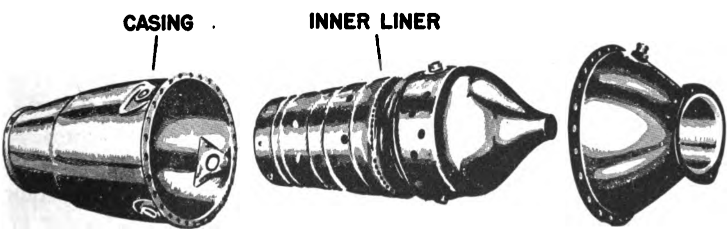


Figure 109.—Combustion chamber assembly.

pressed air from the compressor for combustion. The flame tubes are so constructed that only a small quantity of air mixes with the fuel to support combustion. The bulk of the intake air is admitted to the flame tube in stages for the purpose of diluting and cooling the combustion gases.

EXHAUST CONE ASSEMBLY

The exhaust cone, which is attached to the rear of the unit over the turbine wheel, is a tapered, cylinder-shaped outlet for the exhaust gas. There is a closed, bullet-shaped cone within it, around which the gas is ejected in a gradually expanding jet form (fig. 110). The function of this cone is to eliminate turbulence in the emerging jet.

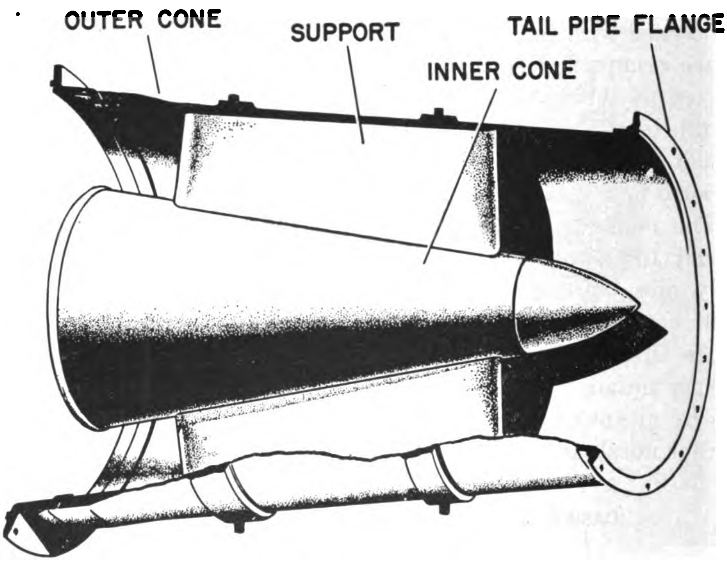


Figure 110.—Typical exhaust cone assembly.

The inner cone is usually supported to the outer cone by streamlined vanes called BRACE ASSEMBLIES. The exhaust cone itself is usually made of stainless steel sheets, reinforced at each end with stainless steel flanges. To keep as much heat

energy as possible within the exhaust cone, it is covered with layers of aluminum foil, aluminum screen, screen cloth, asbestos fiber, and/or other insulating material.

FUEL INJECTION EQUIPMENT

There are several means used for injection, automatic regulation, and control of the fuel supply in various turbo-jet engines. The typical system contains the following units: fuel filter, fuel pump, barometric control device, governor, control valve, drip valve, drain manifold and drain valve, fuel manifold and fuel nozzles, and check valve.

The FUEL PUMP is of the constant displacement type. The GOVERNOR bypasses fuel back to the inlet line of the fuel pump in order to prevent the rotor assembly exceeding the maximum allowable speed. The BAROMETRIC CONTROL DEVICE bypasses the fuel in order to maintain, for a given cockpit setting of the control valve, a constant speed regardless of altitude.

By means of the CONTROL VALVE, the pilot can vary the speed of the engine by changing the amount of the fuel flow to the nozzles. The control valve also functions as a stop cock to completely shut off the flow of fuel. A DRAIN MANIFOLD and DRAIN VALVE are connected to the lower combustion chambers to drain the fuel when the unit is shut down and to avoid fuel accumulation in the chambers.

A FUEL MANIFOLD directs the fuel to the FUEL NOZZLES. The nozzles in the combustion chambers provide equal distribution of fuel in all chambers. A CHECK VALVE, located in the control valve inlet line, prevents a reverse flow of fuel to the barometric control device and governor during operation of the airplane auxiliary fuel pump.

LUBRICATION SYSTEM

Some turbo-jet engines are lubricated by a simple wet-sump system, while others employ the dry-sump system. Oil is delivered under pressure to the points requiring lubrication, but in some turbo-jet engines not all of the units lubricated are scavenged. Some of the lubricated points are ported to the atmosphere.

For general information on the lubrication of turbo-jet engines discussed in this book, see coverage of lubrication systems for the respective engines.

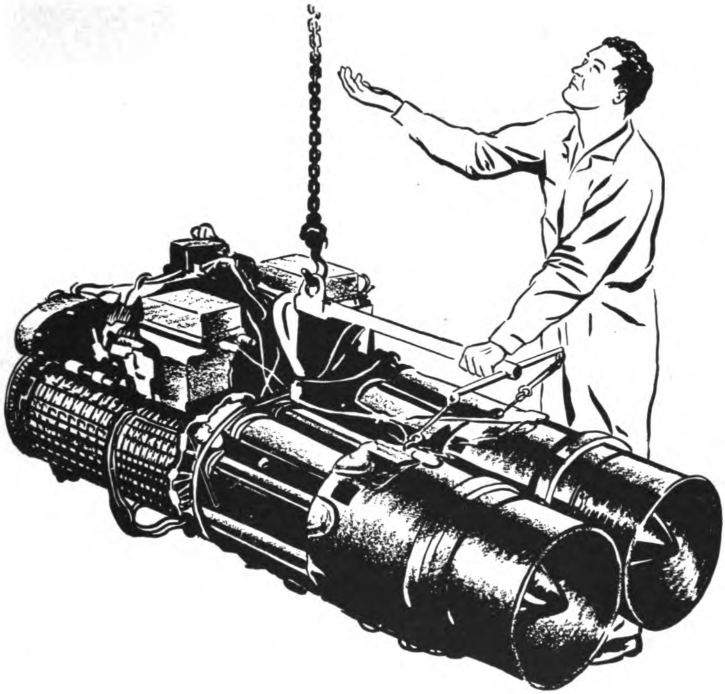
ELECTRICAL SYSTEM

The sole function of the electrical system is to start the engine. Once the engine is operating, the electrical system is not involved in sustaining operation or in stopping the engine.

The system usually includes a starter, a 24-volt d-c battery, two ignition coils, two spark plugs, and the necessary controls and switches.

QUIZ

1. What are the four main classes of jet-propulsion units?
2. What is the chief distinction between the rocket and other jet-propelled units?
3. Name the five main sections of a turbo-jet engine.
4. Name the parts of a combustion chamber.
5. What is the purpose of the inner cone in the exhaust-cone assembly?
6. What is the average warm-up period for a turbo-jet unit?
7. What is the function of the turbine in a turbo-jet engine?
8. What is the function of the cross-over tubes?
9. What is the biggest disadvantage in using a radial-flow air compressor to handle a large volume of air?



CHAPTER 11

T–40 TURBO–PROP ENGINE

The models T40–A–4A and T40–A–4B turbo-prop engines incorporate a dual power unit composed of two similar gas turbine power sections and a remote reduction gear assembly. This assembly is driven through separate extension shafting by each power section.

Differences between the models lie in their extension shafts. Model T40–A–4A engines incorporate extension shafts which are 105.55 inches in length, while the T40–A–4B engines include shafts which are 117.6 inches in length.

PRINCIPLES OF DESIGN AND OPERATION

Each power section includes a single-entry, multistage axial flow compressor; a set of eight cylindrical, flow-type combus-

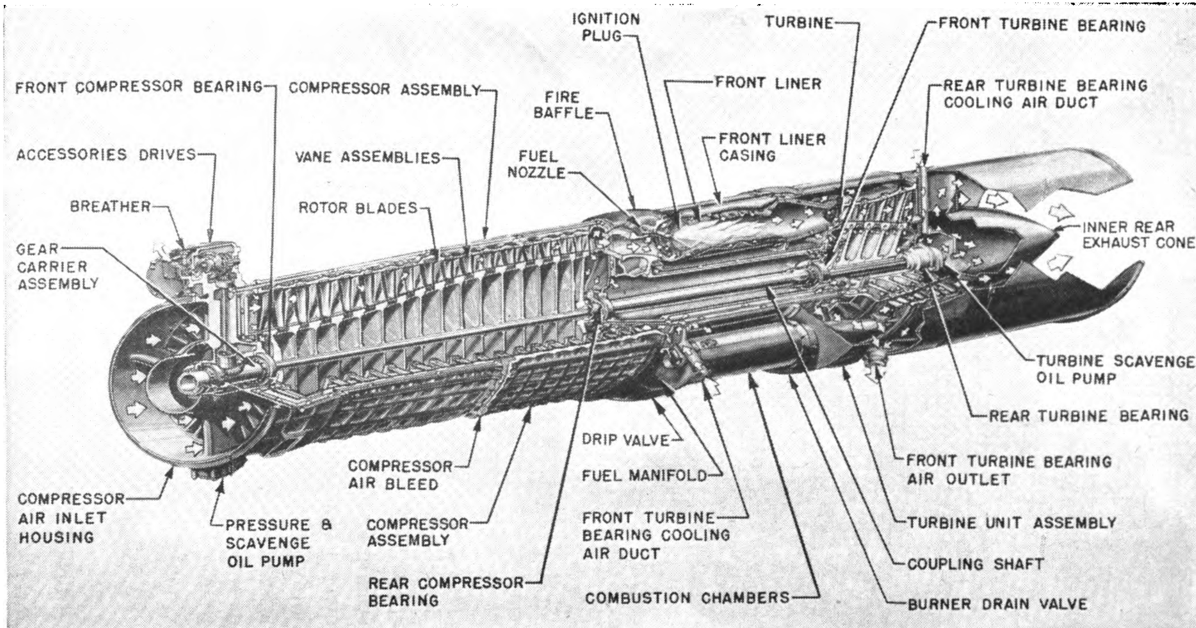


Figure 111.—Power section nomenclature.

Figure 111.—Power section nomenclature.

tion chambers; and a multistage turbine. Figure 111 shows power section nomenclature.

The COMPRESSOR ASSEMBLY incorporates a 17-stage rotor encased in a two-piece casing. The compressor rotor is connected to the four-stage TURBINE ROTOR by a splined coupling shaft and a tie bolt.

Each COMBUSTION CHAMBER ASSEMBLY consists of two concentric passages formed by inner and outer liners.

An accessories drive housing is incorporated on the top of a compressor air inlet housing which is bolted to the front of the compressor casing.

Each power section is connected to the reduction gear assembly by three lengths of extension shafts which are supported by two intermediate bearings.

The REDUCTION GEAR ASSEMBLY includes a gear train consisting of two stages of reduction driving concentric propeller drive shafts. The first stage reduction is accomplished by a set of spur gears; the second stage by a compound planetary system. Friction clutches—one for each power section—are provided in the reduction gear assembly and permit the operation of both propeller shafts by either power section.

During operation, air enters each power section through the compressor air inlet housing and passes through the 17-stage compressor, as demonstrated in figure 112. From the compressor, the air flows through the diffuser into eight combustion chambers. In each chamber, the air enters through a series of holes into the front liners, where fuel is introduced and the fuel-air mixture burned. The hot gases exit from the opposite end of the combustion chambers and pass through the turbine, causing it to rotate. The turbine, in turn, drives the compressor rotor and propeller reduction gears. From the turbine, the gases travel through an aperture formed by the inner rear exhaust cone and the rear turbine bearing support.

DUAL POWER UNIT

The dual power unit consists of a left power section and a right power section. These power sections are secured to each other by tie brackets attached to the top and bottom of the sections at the forward and aft ends of the compressor casings.

POWER SECTION

Each power section includes a multistage axial flow compressor, eight combustion chambers of the cylindrical throughflow type, a multistage turbine, and an accessories drive housing. Oil, fuel, and cooling air systems as well as a coordinating control are provided.

COMPRESSOR ASSEMBLY

The compressor assembly is composed of a compressor air inlet housing, a compressor rotor assembly, and a compressor casing.

The AIR INLET HOUSING is a one-piece magnesium casting and includes the gear carrier assembly which provides the drive for the main oil pump and the accessories. A set of inlet guide vanes are used to direct the air through the compressor blades and to prevent the entrance of large foreign objects. Two horizontal and two vertical struts which support the gear carrier are designed so that deicing is accomplished by passing hot air through the horizontal struts and oil through the vertical struts.

The axial flow COMPRESSOR ROTOR ASSEMBLY consists of 17 steel wheels splined to a shaft supported by a roller bearing at the front and by a ball bearing at the rear. A continuous circle of steel compressor blades are pinned to the outer rim of each wheel. Balancing weights are pinned to each end of the wheel assembly.

The COMPRESSOR CASING encloses the compressor rotor assembly. This casing consists of two magnesium alloy castings bolted together along a horizontal split line. Two-piece steel compressor stators (vane assemblies) are held in position in each half of the casing by vane rings, or clips. The compressor air inlet housing is bolted to the front of the compressor casing. The compressor diffuser is bolted to the rear of the casing.

Fuel nozzles installed in the diffuser align with domes which protrude from the combustion chambers into the diffuser passages.

COMBUSTION CHAMBER ASSEMBLY

The combustion chamber assembly includes eight stainless steel chambers mounted circumferentially around the turbine bearing support housing. Essentially, each chamber consists of two concentric passages formed by inner and outer liners. Compressed air enters each chamber through a dome assembly and passes through a series of holes into the front liners. This is shown in figure 113. Fuel is sprayed by the nozzles into the front inner liners, and the fuel-air mixture burned. The resulting gases exit from the chamber through the rear inner liner and pass into the turbine.

The dome is secured to the front liner by a tube spanner nut, and is supported by the diffuser housing. Three piston ring-type seals permit linear expansion during engine operation. An igniter plug, used only for starting purposes, is provided in each of two diametrically opposed domes. The front inner liner is secured in position by a locating dowel installed through the outer liner. The front liners, in turn, are secured by a tube spanner nut to the turbine diaphragm and front casing assembly. The front lip of the two-piece rear liner is held in place between the front inner and outer liners by a spring lock. The rear lip of the rear liner is placed in a mating opening formed by the No. 1 turbine vane assembly and the front turbine bearing support assembly.

Adjacent front inner liners are connected by inner cross-over tubes placed within outer cross-over tubes. The latter tubes connect adjacent front outer liners. Six piston ring-type seals placed between the inner and outer tubes are secured in position by a clamp which is designed to prevent gas leakage while permitting expansion and contraction of the unit.

TURBINE UNIT ASSEMBLY

The turbine unit assembly includes three major components —turbine support, turbine rotor assembly, and turbine casing assembly.

Designed to support the turbine rotor assembly, the TURBINE SUPPORT is attached to the rear flange of the compressor casing, as may be seen in figure 114. Because of its proximity to the

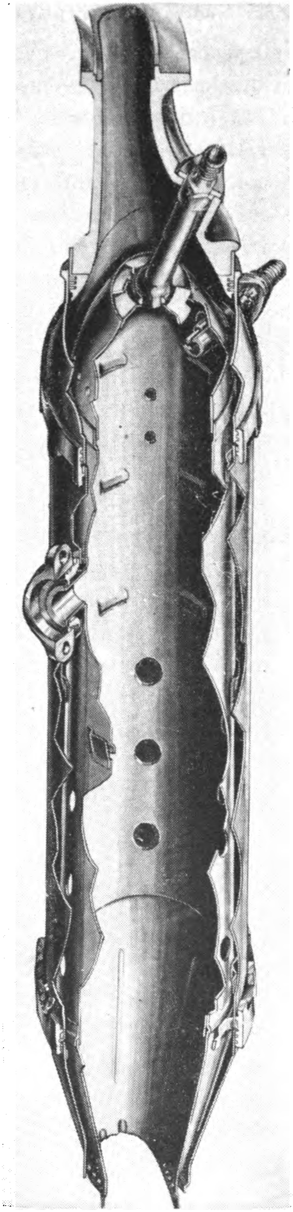
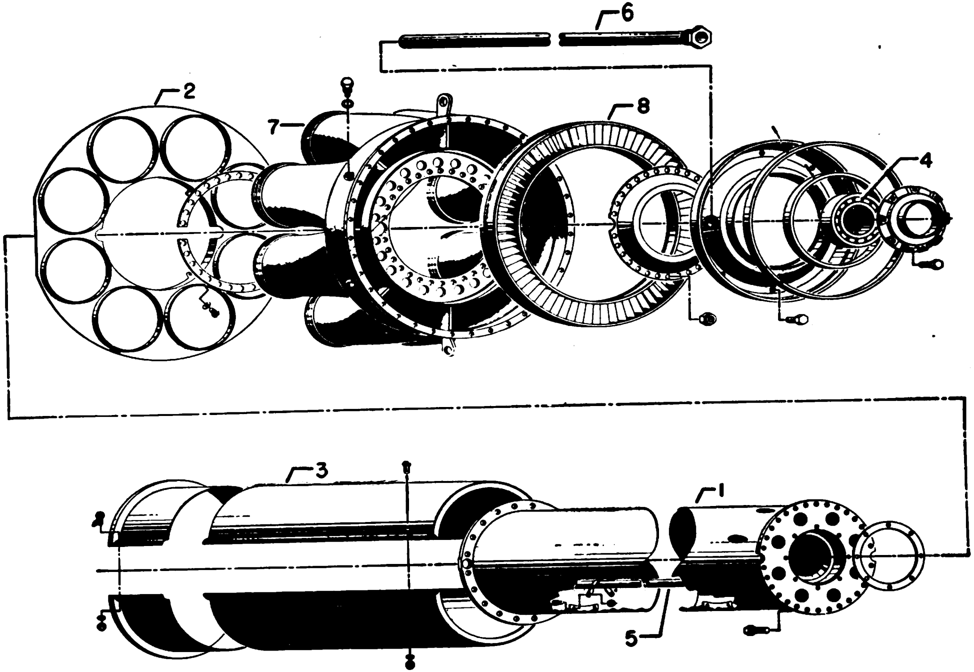


Figure 113.—Combustion chamber.



1. Turbine front support.
2. Turbine front vane casing baffle.
3. Turbine support air duct (air seal shroud).
4. Roller bearing.
5. Turbine support housing oil scavenge tube.
6. Thrust balance air tube.
7. Turbine front vane casing assembly.
8. Turbine front vane.

Figure 114.—Turbine front support details.

combustion chambers, the turbine support is cooled by air which circulates through the annulus formed by the support and a surrounding air seal shroud. This shroud incorporates the thrust balance tube which transmits air from the compressor to the front face of the No. 1 turbine wheel in order to offset the thrust effects of the rotor assembly.

The TURBINE ROTOR ASSEMBLY incorporates four steel wheels splined to the turbine rotor shaft which is supported by two roller bearings. This is illustrated in figure 115. Secured to the outer rim of each wheel is a continuous circle of Vitallium blades.

The rotor assembly is encased in the TURBINE CASING ASSEMBLY and includes two-piece stator (vane) assemblies similar to those provided in the compressor casing.

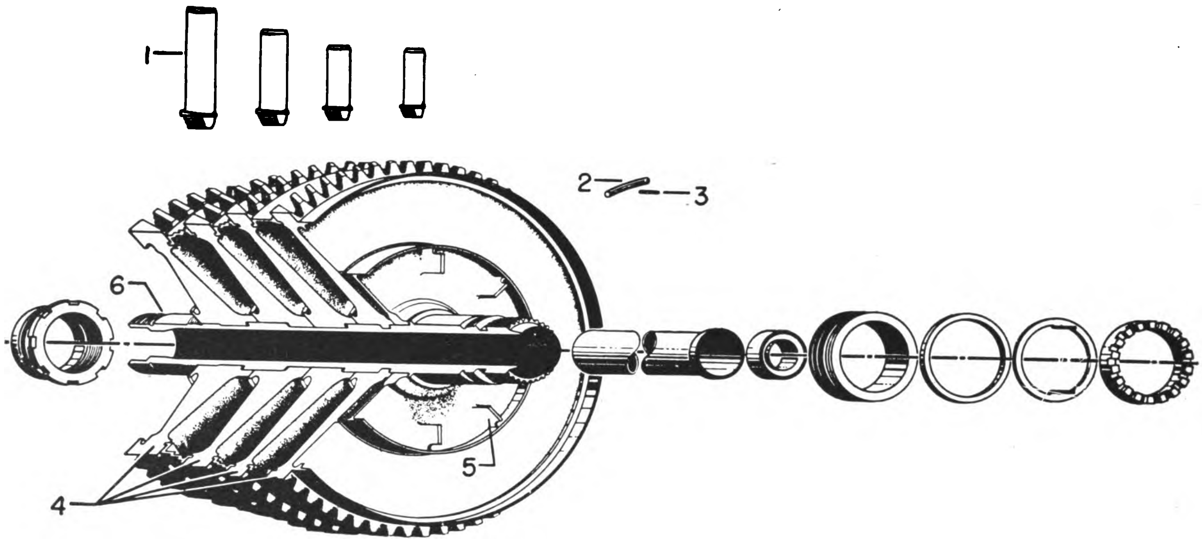
The casing is surrounded by a circular shroud which permits cooling air circulation around the unit. Bolted to the rear flange of the casing is the turbine rear bearing support which incorporates six hollow, slotted supporting struts through which rear bearing cooling air escapes to the exhaust gas stream. Attached to the support, the inner exhaust cone design permits the expansion of the exhaust gases and serves as a cover for the turbine scavenge oil pump. The rear flange of the turbine unit assembly permits the use of an engine-furnished quick-disconnect clamp to secure the aircraft tailpipe to the power section.

ACCESSORIES DRIVE HOUSING

A magnesium alloy accessories drive housing is incorporated on top of the compressor air inlet housing. Mounting pads are provided for the fuel control, the primary fuel pump, and the secondary fuel pump on the rear face of the assembly. A mounting pad for a tachometer generator is provided on the front face of the assembly.

The gear carrier assembly drives the accessories drive pinion shaft assembly to which is splined the center accessories drive gear shaft assembly. The spur gear of this assembly meshes with several shaft gears to form the accessories drive gear train.

An engine breather is located on the top face of the housing.



1. Turbine Blade
2. Balancing Weight
3. Pin
4. Turbine Wheel
5. Turbine Cooling Air Fan
6. Turbine Shaft

Figure 115.—Turbine rotor assembly details.

OIL SYSTEM

Each power section incorporates an independent dry sump oil system which includes one combination main pressure and scavenge oil pump assembly and two separate scavenge pumps.

The gear-type main pump (fig. 116) is located on the bottom of the compressor air inlet housing, and is driven by the gear carrier assembly. Oil is supplied to the pressure pum from the aircraft-furnished external tank. This oil is de livered through an oil filter to the pressure distribution systen The filter contains a check valve set to open at 1.5 p.s.i. diffe ential pressure. It is designed to prevent oil in the syste from draining back through the pump when the power sectio is shut down. A pressure relief valve, located at the filter out let, limits the oil pressure delivered by the pump to a maximun of approximately 175 p.s.i.

Oil is directed through a drilled passage in the lower vertica strut of the compressor air inlet housing to the gear carrie assembly. Part of the oil is diverted to the accessories driv housing, and the remainder is used to lubricate the rotor bear ings. Oil for lubrication of the turbine rotor and gear com pressor rotor bearings is directed from an annular chambe around the gear carrier to the inside of the carrier shaft an then through the center of the drilled tie bolts. Drilled pa sages in the tie bolts, turbine shafts, and the 17th-stage com pressor wheel hub permit oil distribution to the rotor bearing

Oil is transferred from the gear carrier assembly to the ac cessories drive housing through a drilled passage in the uppe vertical strut of the compressor air inlet housing. The o which passes through the vertical struts serves as a deicir medium. A pressure reducing valve in the housing reduces tl relatively high discharge pressure of the pump to appro mately 30 p.s.i. A portion of the reduced pressure oil trav to the accessories mounting pads through drilled passag The remainder is sprayed onto the gear train through small orifices in order to lubricate the gears and bearings in housing. The oil drains through a passage surrounding accessories drive pinion shaft and falls upon the gears bearings of the gear carrier assembly, lubricating the carr

components as well as the front compressor bearing. A passage surrounding the oil pump drive shaft gear permits the oil to drain back to the inlet of the main scavenge pump.

Oil from the rear compressor and front turbine bearings drains to the inside of the front turbine support. There it is picked up by the gear-type turbine support scavenge pump located in the diffuser assembly (fig. 116). The scavenge

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OIL SYSTEM

Each power section incorporates an independent dry sump oil system which includes one combination main pressure and scavenge oil pump assembly and two separate scavenge pumps.

The gear-type main pump (fig. 116) is located on the bottom of the compressor air inlet housing, and is driven by the gear carri

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components as well as the front compressor bearing. A passage surrounding the oil pump drive shaft gear permits the oil to drain back to the inlet of the main scavenge pump.

Oil from the rear compressor and front turbine bearings drains to the inside of the front turbine support. There it is picked up by the gear-type turbine support scavenge pump located in the diffuser assembly (fig. 116). The scavenge pump contains three gears, and is driven through a work gear off the 17th-stage compressor wheel. The pump incorporates two inlet ports and one outlet port in order to permit the pump to scavenge oil from two locations and return it through a common discharge line to the aircraft tank.

The turbine front support provides a well at the forward end, directly beneath one inlet port of the pump. When the aircraft is in a nose-down attitude, the scavenge oil encased by the support flows to this well to be picked up by the pump. Similarly, a well at the rear of the support connects to the other inlet port so that the scavenge oil settles in the rear well when the aircraft is in a nose-up attitude.

The vane-type turbine scavenge pump scavenges the oil which drains from the rear turbine bearing and directs it forward through the turbine shaft to lubricate the splines of the coupling shaft, turbine shaft, and 17th-stage compressor wheel.

FUEL SYSTEM

The principal components of the power section fuel system are: primary fuel pump, secondary fuel pump, fuel filter, fuel control, fuel nozzles, drip valve, and burner drain valve.

The primary and secondary gear-type pumps are identical in construction and have the same capacity. As shown diagrammatically in figure 117, the fuel system is arranged so that the two pumps actually are connected in series with one filter element located between the pumps and the second filter element placed in the outlet line to the fuel control.

If the primary pump has a higher efficiency than the secondary pump during normal operation, the check valve located between the filter elements is opened, bypassing the excess fuel flow from the primary pump directly to the secondary filter.

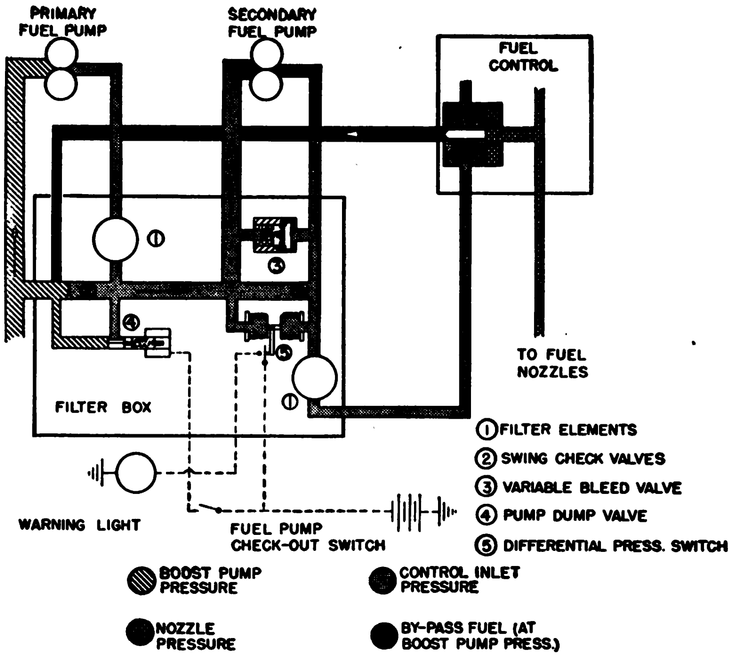


Figure 117.—Normal operation of fuel system (fuel supplied by primary pump —primary pump efficiency high).

If the secondary pump has a higher efficiency than the primary pump during normal operation, the variable bleed valve incorporated in the filter box bypasses the quantity of fuel required to prevent the secondary pump from "taking over." However, the variable bleed valve will not close completely until the primary pump fails totally.

A partial failure of the primary fuel pump results in a pressure rise of over 50 p.s.i. through the secondary fuel pump. Such failure causes the differential pressure switch to close. When this happens, a warning light is flashed.

If the primary fuel pump suffers total failure, the following events take place. When the pressure rise through the secondary pump reaches 50 p.s.i., the differential pressure switch closes. When the pressure rise reaches 175 p.s.i., the pressure differential becomes greater than the spring force in the vari-

able bleed valve. The valve closes, causing the secondary pump to take on the full load. The check valve located in the bypass line around the primary fuel pump then opens. This permits the direct delivery of fuel from the inlet fitting to the secondary pump inlet.

When the secondary fuel pump suffers a partial or total failure, the check valve between the two filter elements opens. Thus, the secondary fuel pump is bypassed, and the primary pump furnishes the fuel required to maintain engine speed.

By energizing the pump dump valve, you can give the operation of the secondary pump a preflight check. The output of the primary pump is then bypassed to the inlet side of the system. The resulting increased pressure rise across the secondary pump closes the differential pressure switch and turns on the warning light. If the secondary pump successfully maintains engine speed with the light on, the check is considered satisfactory.

A FUEL CONTROL SYSTEM is mounted on the rear face of the accessories drive housing. This assembly provides a means of varying fuel flow in order to permit a selection of engine power that is coordinated with propeller pitch and engine speed. You will consider the fuel control assembly in detail in a later section of this chapter.

From the fuel control assembly, the fuel flows through a manifold assembly to a fuel nozzle in each combustion chamber.

A spring-loaded, flat-plate drip valve is located on the bottom of the fuel manifold. It is designed to drain the manifold when manifold pressure drops below 2 p.s.i. while the power section is being stopped. The valve also prevents fuel from dripping into the combustion chambers at extremely low pressures.

The burner drain valve is located on the bottom of the diffuser assembly. The spring-loaded flat-plate valve drains the combustion chamber and diffuser so as to prevent the accumulation of fuel in the power section after an unsuccessful start or after stopping the engine.

The FUEL CONTROL is located on the outlet side of the engine-driven fuel pumps. Figure 118 shows the T–40 engine fuel control unit.

Pressure of the fuel entering the assembly from the pumps is regulated by the bypass and relief valve assembly. This consists of one spring-loaded valve within another spring-loaded valve. The outer (bypass) valve movement is controlled by a large spring and the pressure differential across the valve diaphragm. The valve regulates the amount of fuel bypassed to the inlet side of the primary pump. Thus, a constant pressure differential is maintained between fuel pump discharge pressure and metered fuel pressure (manifold pressure).

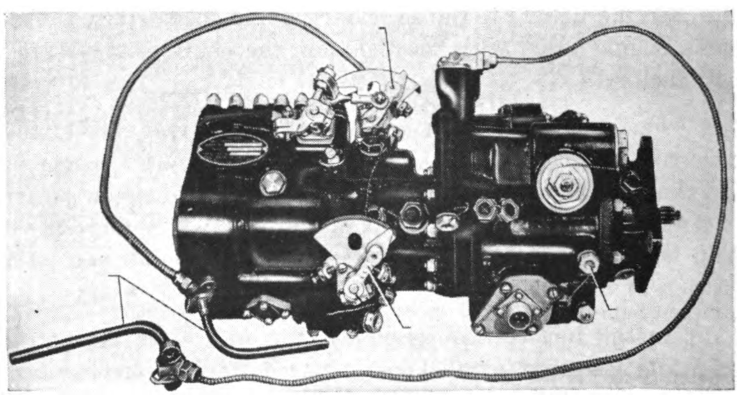


Figure 118.—Fuel control unit.

The inner, or relief, valve movement is controlled by a smaller, stiffer spring than the bypass valve spring.

The maximum pressure relief valve serves two purposes. First, the relief valve is designed to open at a pressure which will maintain a maximum predetermined pressure at the fuel nozzles. Thus, with a given nozzle configuration, the maximum fuel flow to the engine will be consistent with permissible engine power loading. The valve thus prevents overloading of the engine reduction gearing under conditions of high com-

pressor inlet densities. Second, the valve prevents excessive pressure build-up in the system during an emergency shut-off at a high engine speed.

The fuel then flows to the regulator valve. Here the unmetered fuel pressure is adjusted to a value which will maintain the desired metering head across the main throttle valve. The DESIRED METERING HEAD is unmetered fuel pressure minus metered fuel pressure.

The size of the predetermined metering head is the function of two factors: first, of the spring loading on the regulator valve diaphragm; second, of a density compensating system.

The DENSITY COMPENSATING SYSTEM consists of two elements. The first element provides an evacuated bellows controlling the position of a contoured needle in response to compressor inlet temperature. Fuel flow varies directly with changes in compressor inlet pressure. It varies inversely with changes in compressor inlet temperature.

The temperature regulates the position of the contoured needle. This in turn determines the amount of fuel entering the compensating fuel pressure chamber from the unmetered fuel chamber. This same amount of fuel must flow from the compensating pressure chamber, past the pressure compensating needle, and into the metered fuel chamber. Because the position of this needle is regulated by the pressure bellows, the flow will be proportional to the density.

Therefore, you can see that an increase in compressor inlet pressure reduces the compensating pressure chamber exit bleed area so that the pressure is increased—that is, for a given inlet bleed area. The pressure differential across the regulator valve diaphragm, in turn, is unbalanced. Then the regulator valve moves toward the open position to re-establish the spring balance. Thus the unmetered fuel pressure is increased. This results in an increased flow to the engine.

Just the reverse of this correction takes place with decreasing compressor inlet pressure.

In the same manner, a decrease in compressor inlet temperature opens a larger entrance bleed area. The result of this is an increased bleed flow. So you see that for a given compressor inlet pressure, this increase in bleed flow results in a

greater fuel flow to the engine due to the increased unmetered fuel pressure.

Unmetered fuel flows from the regulator unit to the throttle valve. The throttle is controlled either by the operator for part throttle operation or by a speed signal for maximum temperature and surge limits. During part throttle operation, the operator has direct control of the valve through the throttle lever.

During a rapid acceleration, the throttle opening is modified by a compound cam arrangement incorporating a single cam follower. A maximum temperature limiting cam and a surge limiting cam are each positioned by a speed sensing piston. The surge limiting cam position is, in addition, biased by compressor inlet temperature.

The governor operates at ground idle, operational idle, takeoff, and reverse thrust to control fuel flow by regulating the main throttle outlet area. This is accomplished by means of a sleeve type valve located within the main throttle valve, positioned by a spring-loaded diaphragm. The spring force on the diaphragm is established by the governor lever position and is opposed by the hydraulic pressure generated by a centrifugal fuel impeller.

Besides establishing a regulator spring setting for normal operation, the ELECTRONIC TEMPERATURE CONTROL SYSTEM also limits fuel flow so that excessive turbine inlet temperature will not result.

A solenoid cutoff valve is incorporated in addition to the manual cutoff valve. The solenoid valve is normally open. When the cockpit throttle is moved out of cutoff to the starting position, the manual cutoff valve opens. This energizes the solenoid, closing this valve. The solenoid valve remains closed until the engine reaches a predetermined speed, at which time a switch is opened. The opening of this switch de-energizes the solenoid, opening the valve to permit fuel flow.

COOLING AIR SYSTEM

Air cooling is required for both the front and rear turbine bearings, as shown in figure 112.

Cooling air for the rear turbine enters a cooling air inlet duct which is part of the turbine bearing support assembly. A portion of this air passes between the bearing retainer and the rear turbine bearing support housing. This air then exits into the exhaust gas stream immediately aft of the last turbine wheel. The rest of the cooling air circulates around the rear surfaces of the bearing and turbine scavenge pump components. This air then flows through a hole in the rear turbine bearing cage housing cover, into the turbine rear support struts, and out through a slot in the trailing edge of each strut into the exhaust gas stream.

Cooling air for the front turbine bearing enters the engine through a cooling air inlet duct in the compressor diffuser assembly. It flows rearward around the front turbine bearing support housing to the front bearing. The air then passes radially outward into an annular chamber formed by the turbine bearing support housing and the turbine casing. From there, the air is discharged through an outlet duct.

COMPRESSOR AIR BLEED

Each section has four compressor air bleed connections. From these connections, air bled from the compressor ninth stage may be taken for purposes of cabin conditioning, instrument operation, and airframe anti-icing.

EXTENSION SHAFTING

Each power section is individually connected to the reduction gear assembly by three extension shafts. These are supported by two intermediate bearings. Each bearing assembly incorporates ball bearings.

Each rotating shaft is encased in a stationary air-seal support housing which prevents the sucking of grease from the bearings into the compressor air inlet.

REDUCTION GEAR ASSEMBLY

The reduction gear assembly incorporates contra-rotating propeller drive shafts, an independent dry sump oil system, two friction clutches, and a propeller brake. (See fig. 119.)

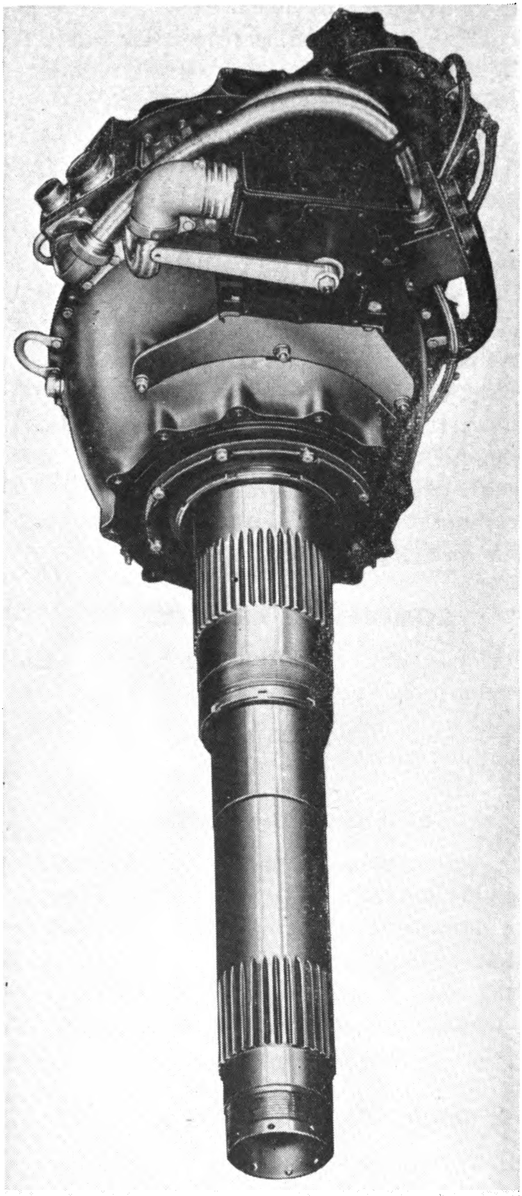
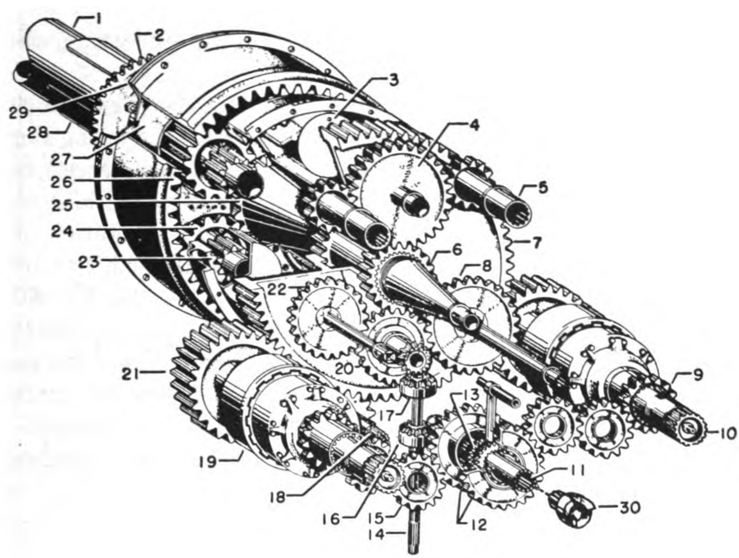


Figure 119.—Three-quarter left front view of reduction gear assembly.

MAIN REDUCTION GEAR TRAIN

The main reduction gear train consists of two stages of reduction. The spur gear-type first stage has a reduction ratio of 2.675:1. The compound planetary type second stage has a reduction of 5.857:1. This results in an overall reduction of



1. No. 60L prop. shaft assembly.
2. Propeller shaft nose pump drive gear.
3. Planet rear carrier.
4. Generator drive idler gear.
5. Generator drive shaftgear.
6. Accessory drive gear.
7. Reduction drive shaftgear.
8. Hydraulic pump drive gear assembly.
9. Clutch shaft starter gear.
10. Clutch inner member assembly.
11. Starter shaft assembly.
12. Starter shaft drive gear.
13. Starter shaft clutch.
14. Oil pump drive shaft.
15. Starter drive idler gear.
16. Alternate clutch drive bevel gear.
17. Oil pump clutch drive gear.
18. Propeller brake shaftgear assembly.
19. Friction clutch.
20. Pump drive gear assembly.
21. Reduction gear spur pinion.
22. Tachometer drive gear assembly.
23. Stationary ring gear.
24. Planet gear assembly.
25. Sun gear.
26. No. 80 propeller shaft drive gear.
27. Planet front carrier.
28. No. 80 propeller shaft assembly.
29. No. 80 propeller shaft drive flange.
30. Starter jaw.

Figure 120.—Reduction gear trains.

15.668:1 and a propeller speed of 868 r.p.m. at 13,600 engine r.p.m. The figures referred to in the following descriptive paragraphs are incorporated in figure 120.

The two reduction spur gear pinions (21) are driven counterclockwise by the power sections through friction clutches (19). These pinions drive the first stage reduction gear (reduction drive shaft gear) (7). The sun gear (25) is splined to the reduction drive shaft gear and meshes with the six large gears of the planet gear assemblies (24).

Small gears are fixed on the same shafts with the large planet gears and mesh with the stationary ring gear (23), causing the planet rear carrier (3) to rotate. The planet rear carrier is bolted to the planet front carrier (27) which is bolted also to the No. 60 (inner) propeller shaft. Therefore, the rotation of the planet rear carrier causes the No. 60 propeller shaft to be driven clockwise. The large planet gears drive the No. 80 propeller shaft drive gear (26). The No. 80 propeller shaft drive gear is bolted to the No. 80 propeller shaft drive flange (29), which is splined to the No. 80 (outer) propeller shaft (28). Thus, the No. 80 propeller shaft is rotated counterclockwise, in the direction opposite to the No. 60 propeller shaft.

ACCESSORIES DRIVE GEAR TRAINS

The nose scavenge oil pump is driven off the No. 80 propeller drive shaft by the propeller shaft nose pump drive gear (2). This is bolted to the propeller shaft.

The main oil pump drive shaft (14) is driven either by the alternate clutch drive bevel gear (16) off the starter shaft clutch (13) or by the oil pump clutch drive gear (17) off the accessories drive gear (6) and the pump drive gear assembly (20). In either case, the pump is driven through an overrunning clutch.

The propeller brake (18) is driven by the first stage reduction gear.

Other accessories are driven by the accessories drive gear which is splined to the first stage reduction gear (reduction gear drive shaft gear). Two generator drive shaft gears (5)

are driven by the accessories drive gear through the generator drive idler gear (4); the tachometer drive gear (22) and hydraulic pump drive gear (8) are driven off the accessories drive gear through the (oil) pump drive gear (20).

Two pairs of starter drive idler gears (15) together with the starter shaft drive gear (12) and the input shaft clutch inner member (10) on the turbine side of each friction clutch form the gear train between the starter and the friction clutches. The engagement of either input shaft with the starter shaft (this constitutes the selection of a power section during the engine starting procedure) is accomplished through the solenoid-operated, double-acting splined starter shaft clutch.

OIL SYSTEM

The reduction gear assembly has a sump oil system which includes a main oil pump and nose scavenge oil pump. The main oil pump assembly consists of one scavenge pump, a primary pressure pump, and a secondary pressure pump.

During normal operation, the output of the primary pressure pump is enough to lubricate the reduction gear assembly and to hold the propeller brake in the "off" position. Therefore, the output of the secondary pressure pump is bypassed back to the pump inlet by a pressure oil shuttle valve.

When the clutch is engaged, the system pressure drops below a pre-set value. When this happens, the shuttle valve is operated, stopping the complete bypassing of the secondary pump. The outlet of this pump is then delivered to the main oil lines.

Oil from the pressure pumps is passed through a filter to a check valve. From the check valve, an oil passage leads, first, to the pinion oil nozzles and, second, to the propeller brake. Branches from the main passages lead to the cooling oil valves and, through pressure reducing valves, to the clutch oil valves. The oil flow through these valves is used for clutch operation.

A second passage from the check valve provides oil for the planetary gearing, the No. 80 propeller shaft center bearing, and the inner propeller shaft seal assembly. Branch lines furnish oil to the accessory drive gear oil nozzle and, through a pressure reducing valve, to the hydraulic pump pad.

The nose scavenge pump picks up oil which collects in the front casing during operation in a nose-down attitude and delivers the oil to a common outlet with the main scavenge pump. The main pump scavenges the oil which collects in the rear casing sump and returns the oil through the common outlet to the aircraft supply tank.

FRICTION CLUTCH

A friction clutch of the disc type is provided for ea section. This clutch is located in the reduction gear a and is illustrated in figure 121.

The clutches are identical in design, and provide lowing features:

1. Either power section may be started with on (the propellers being disconnected during the operation).
2. After one power section has been started, the may be picked up through the clutching arra
3. After one power section and the propeller are o the second power section may be started eithe ground or in flight.
4. Either power section may be started from tl milling of the propeller during flight.

The friction clutch is operated by oil pressure. Tl plates are cooled by the oil during engagement. To and disengage the clutch, the oil pressure acts on a acting piston located on the power section side of the

During starting and idling, the motor-driven clutch and cooling oil valve are in the disengaged position. case, the oil pressure to the disengagement chamber engagement chamber is vented to the gear box. Th oil is shut off.

When the power section reaches a speed with suffici to pick up the propeller, a speed sense relay operates tl driven clutch actuating valves, moving them to the position. This action vents the disengagement chamber to gear box, transfers oil pressure to the engagement side of the piston, and opens the cooling oil valve to let the oil flow be-

tween the clutch plates. The cooling oil line is vented to the disengagement chamber, keeping it full of oil.

After engagement is complete, the cooling oil valve is closed by a time relay control. But the clutch oil valve is held in position by an over-center spring. With the cooling oil shut

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The nose scavenge pump picks up oil which collects in the front casing during operation in a nose-down attitude and delivers the oil to a common outlet with the main scavenge pump. The main pump scavenges the oil which collects in the rear casing and returns the oil through the common outlet to the

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tween the clutch plates. The cooling oil line is vented to the disengagement chamber, keeping it full of oil.

After engagement is complete, the cooling oil valve is closed by a time relay control. But the clutch oil valve is held in position by an over-center spring. With the cooling oil shut off, the disengagement chamber is partially drained of oil by a small hole. This increases the axial force of the clutch plates because of the centrifugal pressure of the oil in the engagement chamber. At a pre-set speed, the two clutch unloading valves open due to centrifugal force. This allows more oil to drain from the disengagement chamber and increases the axial force on the clutch.

With one power section and one propeller operating at speed sufficient to sustain the propeller air load and pick up the second power section, the second clutch may be engaged. The speed sense provides protection from false starts.

With both power sections shut off during flight, either section may be started from the windmilling of the propeller. The power sections are started separately in the same sequence as occurs when ground starting the second power section.

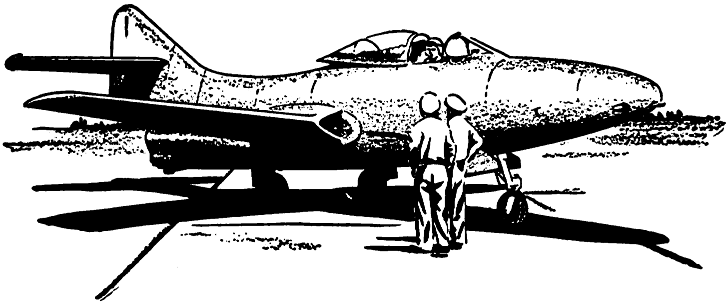
PROPELLER BRAKE

The friction cone-type propeller brake is driven by the first stage reduction gear. During engine operation, the brake is held in the "off" position by oil pressure acting on a piston. When the engine is shut down, the friction clutches are disengaged and the propeller feathered. This reduction in propeller speed decreases the axial force of the oil acting on the piston and, at a predetermined speed, the braking surfaces are brought into contact. This increases the rate of propeller deceleration.

The outer member of the brake operates on a helical thread so that small reverse movement of the propeller causes the brake to be self-energizing. This prevents propeller rotation. When the reverse torque is removed from the brake, a spring forces the outer member to its original position.

QUIZ

1. List two reasons for having a set of inlet guide vanes on the compressor assembly.
2. What is the function of the vane rings or clips in the compressor assembly?
3. Before passing through a series of holes into the front liners of the combustion chambers, compressed air is passed through an assembly. What is it?
4. When the fuel-air mixture is burned, the resulting gases pass from the rear inner liner into another chamber. What is it?
5. Where is the fuel-air mixture burned?
6. What are the three major components of the turbine unit assembly?
7. Explain the means by which the turbine support is cooled.
8. Into what system does the rear bearing cooling air escape?
9. Where is the mounting pad for the tachometer generator located?
10. What is the function of the check valve in the oil system filter?



CHAPTER 12

J33 TURBO-JET ENGINE

The J33 turbo-jet engine is composed of four major sections or sub-assemblies. These sections are shown in figure 122 and are arranged as follows:

1. Accessory drive assembly.
2. Compressor unit.
3. Turbine unit.
4. Exhaust cone.

Model J33 engines have a dual-inlet centrifugal compressor and a single-stage gas turbine rotor. The compressor rotor (or impeller) shaft is connected to the turbine rotor shaft by a coupling sleeve.

Atmospheric air enters on both sides of the compressor casing where it is compressed by the double-inlet, multiple-vaned impeller. The compressed air passes through the air adapters to the combustion chambers (figure 124), where it is admitted through a series of holes into the inner liners (flame tubes). Here fuel is introduced by nozzles, mixed with air, and burned. The exhaust gases leave the combustion chambers through a nozzle diaphragm which directs them on the turbine rotor buckets, after which they enter the exhaust cone and pass out through the tail pipe. The energy of the gases passing through the turbine turns the shaft which drives the compressor and the accessories.

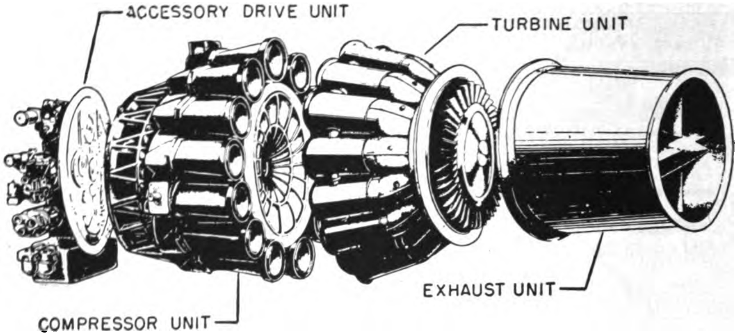


Figure 122.—Major subassemblies of the J33 engine.

ACCESSORIES

The accessory drive assembly is mounted on the front of the unit. It consists of an accessory gear casing, a train of reduction drive gears, an oil reservoir, and the accessories.

The accessory gear case houses the gear train, rotor cage, and oil reservoir. On the front surface of the case are mounted the generator, the starter, the main fuel pump, the tube and scavenge pump, the governor, the tachometer generator, and the hydraulic pump.

All these accessories are driven by means of the reduction gears in the accessory case. These gears, in turn, are driven by the rotor shaft.

Two different GENERATORS are used on the J33-type engine, depending upon the electrical wiring system of the airplane. Both are six-pole, direct-current units with shunt, compensating, and commutating windings. One generator is rated at 6 kilowatts, 200 amperes, 30 volts, at speeds varying from 4,400 to 8,000 r.p.m. The other, a heavy-duty type, is rated at nine kilowatts, 300 amperes, 30 volts, at the same speeds. The generator is mounted on the accessory gear case between the tachometer generator and the fuel pump.

The STARTER is a four-pole, compensated, commutating-type motor, rated at 17 volts, 300 amperes, 8,000 r.p.m. for intermittent operation. It is mounted on the accessory gear case at the front of the unit between the tachometer generator and

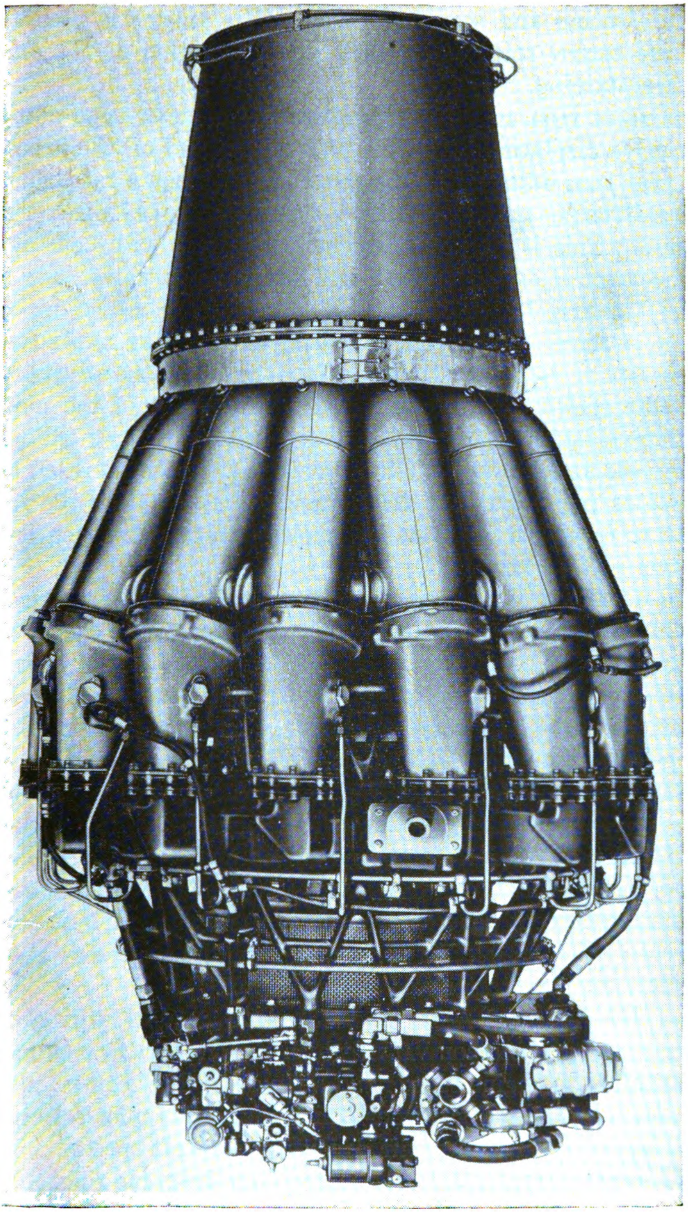


Figure 123.—Left side view of J33–A–8 turbo-jet engine.

the lubricating and scavenge pump. The starter is used turn the engine rotors only until the combustion of the u is self-sustaining.

The MAIN FUEL PUMP is a pressure-loaded, gear-type pu of positive displacement. This unit is mounted on the acc sory gear case adjacent to the generator. It has a rated fl of 20 gallons per minute at 3,400 r.p.m. and 500 p.s.i. discha pressure. This is a single-element gear pump with const displacement at any one speed, and has no relief valve.

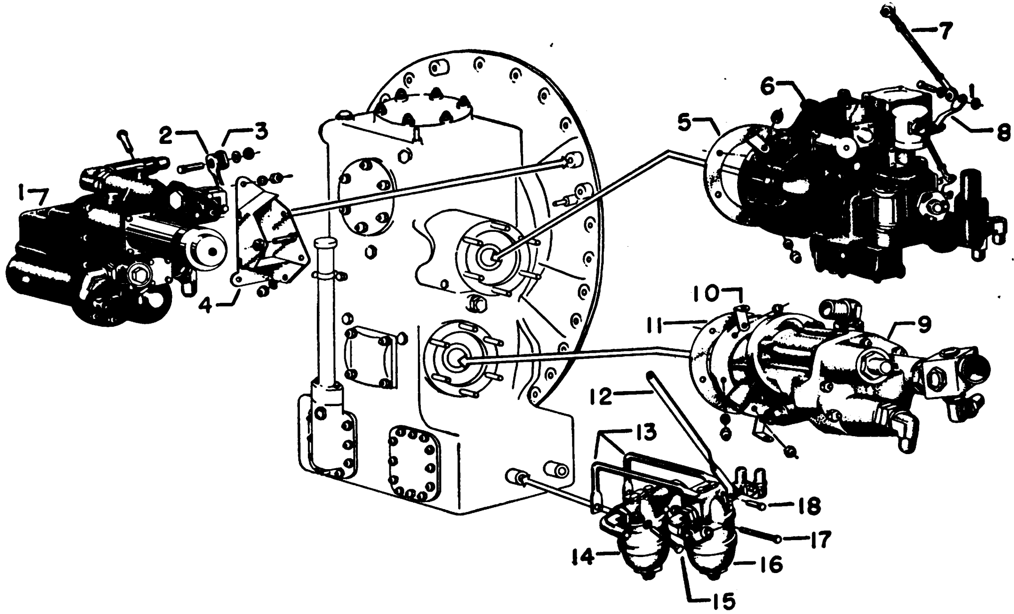
The J33–A–8, J33–A–10, and J33–A–23 models are equip with a mechanically driven, two-element PRESSURE AND SC ENGE PUMP of the rotary type. It is mounted on the access gear case slightly below the center, at the front of the u Its lubricating element is rated to give a flow of three gall per minute at 2,400 r.p.m. Its scavenging element is rated 10 gallons per minute at 2,400 r.p.m. The total power quired to drive the pump at the above ratings is between and two horsepower.

The GOVERNOR is a bypass valve controlled by centrifu weights. The valve acts to prevent overspeed of the engin excess of 11,500 to 11,615 r.p.m. At this speed, the gover rotates at between 3,396 and 3,430 r.p.m. Centrifugal fo causes a weight assembly to move outward and contac spring-loaded spindle which operates a linkage mechanism c trolling the bypass valve. The governor is mounted on accessory gear case at the front of the unit between the f pump and the hydraulic pump mounting pad.

The TACHOMETER GENERATOR is a two-pole, three-pha alternating-current generator which is used with an indica to record rotor speed. It is mounted on the accessory g case between the starter and the generator.

The J33–A–8, J33–A–10, and J33–A–23 models utilize automatic FUEL CONTROL VALVE which meters fuel in respon to variations in engine speeds and altitudes. This control al provides an all-speed governor which maintains pilot-select engine speed regardless of air density or aircraft speed.

The DRIP VALVE is a flat disk seated on a neoprene ring. I purpose is to drain the fuel manifold of all fuel when fuel pres sure within the manifold is below 5 p.s.i. The valve is con



1. Emergency fuel control.
2. Emergency control throttle lever.
3. Emergency control throttle lever block.
4. Emergency control mounting bracket.
5. Gasket.
6. Main fuel control.
7. Emergency control-to-main control link assembly.
8. Main control throttle lever.
9. Dual fuel pump.
10. Bracket.
11. Gasket.
12. Emergency filter bracket strut.
13. Emergency filter bracket.
14. Main fuel filter.
15. Bolt.
16. Emergency fuel filter.
17. Bolt.
18. Bolt.

Figure 125.—Fuel system accessories.

nected to the lower part of the fuel manifold in alignment with combustion chamber No. 8.

The COMBUSTION CHAMBER DRAIN VALVE is also a flat disk seated on a neoprene ring. Used to drain the combustion chambers of any unburned fuel, it is located under the adapter for the bottom combustion chamber. The valve is connected to a drain manifold which is joined to the seven lowest adapters. Unburned fuel in the upper chambers drains by gravity flow into the lower chambers. This valve is designed to open and allow fuel to drain overboard when fuel pressure within the combustion chambers falls below 2 p.s.i. gage pressure.

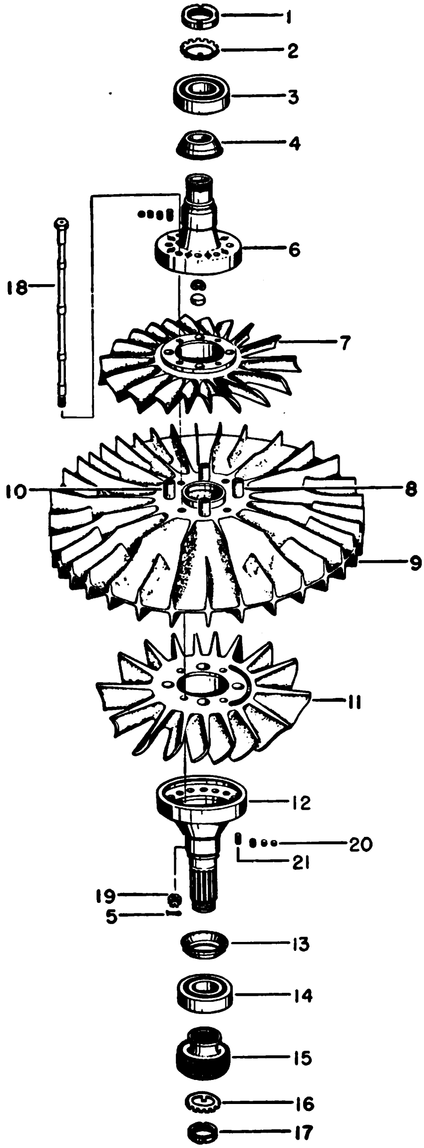
The two SPARK PLUGS are of the porcelain core type, and have electrodes long enough to extend into the combustion chambers. These plugs are mounted in air adapters on the lower right and upper left sides of the engine as you view it from the rear.

A spring-loaded CHECK VALVE in the fuel inlet line to the control valve prevents reverse flow of fuel through the main fuel control, in the event that the airplane auxiliary fuel pump is in operation.

The LUBRICATING OIL FILTER is a wire mesh-type filter designed to remove foreign matter from the oil feed lines. It is mounted on the discharge side of the lubricating and scavenge pump. All oil passing through the lubricating element of the pump is filtered before being passed on to the rest of the system.

The J33–A–8, J33–A–10, and J33–A–23 models incorporate an air maze removable (filter screen) stack type FUEL FILTER. The filter is mounted between the aircraft booster pump and the inlet of the engine driven fuel pump and filters all fuel entering the main engine fuel system.

A continuous spark is provided at the engine spark plugs during starting by two IGNITION BOOSTER COILS mounted on the engine and wired in parallel. The coils receive power from the engine starter relay through the single-pole, double-throw ignition booster switch in the cockpit. Operating the starter switch to start the engine automatically operates the booster coils.



1. Retaining nut.
2. Tab washer.
3. Ball bearing.
4. Oil slinger.
5. Cotter pin.
6. Impeller front shaft.
7. Front guide vane assembly.
8. Dowel.
9. Impeller.
10. Dowel.
11. Rear guide vane assembly.
12. Rear impeller shaft.
13. Oil slinger.
14. Roller bearing.
15. Compressor rotor coupling hub.
16. Tab washer.
17. Retaining nut.
18. Impeller bolt.
19. Impeller nut.
20. ¼-in. balancing plugs.
21. ½-in. balancing plugs.

Figure 126.—Exploded view of compressor rotor assembly.

COMPRESSOR UNIT

The compressor unit is comprised of a rotor, a compressor casing, a diffuser, bearing supports, guide blades, and truss rings.

The COMPRESSOR ROTOR consists of a double-sided, multiple-vaned impeller to which a stub shaft is bolted on either side. The rotor is supported by a ball bearing on the front side and a roller bearing on the rear (fig. 126).

The COMPRESSOR CASING consists of two half-casings which are separated axially by the diffuser.

The DIFFUSER is cast with 14 identical air channels which conduct the compressed air into the air adapters leading to the combustion chambers.

A TRUSS RING is bolted to each side of the compressor casing, and serves to support the compressor BEARING SUPPORTS. The GUIDE BLADES occupy the space under the truss rings and direct the ram air into each side of the impeller. The guide blades are covered with a protective screening which prevents foreign matter from entering the unit.

The diffuser of the compressor is connected to the ring and tube assembly of the turbine unit by 14 AIR ADAPTERS and SPACERS. The spacers adjoin the diffuser openings. The combustion chamber end of each air adapter is recessed to absorb the tube expansion caused by the heat. Each air adapter contains a dome-and-nozzle assembly through which the fuel is injected into each combustion chamber.

ROTOR ASSEMBLY

The COMPRESSOR ROTOR and the TURBINE ROTOR are united by a sleeve-coupling assembly to form the complete rotor assembly. The assembly revolves on four high-speed antifriction bearings. The front shaft of the compressor rotor is splined to the coupling shaft which drives the gears of the accessory drive assembly.

TURBINE UNIT

The turbine unit consists of a turbine wheel and shaft, a nozzle diaphragm, and a series of combustion chambers called the ring-and-tube assembly.

The low-alloy steel shaft is flash welded to the heat-resistant steel wheel. Securely dovetailed into the outer rim of the wheel is a continuous circle of curved blades. The end of the shaft opposite the wheel is splined to fit the coupling which joins the turbine shaft to the compressor shaft.

The nozzle diaphragm is composed of two spacer rings which support a full circle of curved blades designed to direct the gas against the blades on the wheel. A third ring, which supports the diaphragm in the turbine unit, has a baffle welded to it to prevent the exhaust gases from overheating the rear bearing.

The ring-and-tube assembly in which combustion takes place consists of 14 interconnected stainless-steel cylinders which converge on a supporting ring. Each tube contains a removable liner which is joined to its adjacent liner by means of cross-over tubes. Each tube is equipped with a piston ring arrangement which enables the tube to slide into the air adapter to absorb the expansion caused by the heat of combustion and to prevent air leakage.

The turbine bearings are housed in the turbine bearing support which is located in the center of the ring-and-tube assembly.

EXHAUST CONE

The exhaust cone is a tapered, cylinder-shaped outlet for the exhaust gas. A closed, bullet-shaped cone inside the exhaust cone permits ejection of a gradually expanded jet. The exhaust cone is bolted to the rear end of the unit over the turbine wheel. The inner cone is supported within the outer cone by four streamline vanes, called brace assemblies.

The exhaust cone is made of stainless-steel sheets, reinforced at each end with stainless-steel flanges. To keep as much of the heat energy as possible within the exhaust cone, it is covered with a layer of aluminum screen, a layer of aluminum foil, a layer of monel screen cloth, a layer of inconel knutted mesh, a layer of Amosite asbestos fiber, and a layer of inconel crimp knit mesh. The outer layer of screening is laced together with stainless-steel wire.

LUBRICATION SYSTEM

The unit is lubricated by a simple wet sump system (fig. 127). The supply reservoir is an integral part of the accessory drive gear casing and is formed by the gear casing and the front bearing support casing.

Lube oil is delivered under pressure to the bearings by me of a two-element lube and scavenge pump. The pump located on the accessory gear casing and has a port on mounting flange which is in direct contact with the oil in reservoir. The lube oil passes from the lube element of pump to an oil filter, and then through external tubing to four rotor bearings and the couplings. Oil is directed into couplings and bearings through a series of six oil jet nozzles.

Oil is returned to the reservoir by gravity and pump suctic The front compressor bearing and the shaft of the accesso drive both drain directly into the reservoir. The oil from t three other bearings and from the coupling drains into a sum from the sump it is drawn by the scavenge element of the lu and scavenge pump to the oil reservoir.

All of the gears and bearings in the accessory drive casi are lubricated by means of a splash system emanating from th gear which drives the lube and scavenge pump. This gear located in a special compartment under the oil level. Oil admitted to the compartment through an orifice which control the quantity of oil used for lubricating the gears and bearings and prevents the oil in the reservoir from being churned into foam.

A baffle in the reservoir prevents surging of the oil during maneuvers and negative accelerations. The lube pump runs dry under inverted flight conditions, but the spline and gear couplings will operate for short periods without being damaged. A vent tube, which passes over the gear case, vents the reservoir to the aft section of the airplane nacelle. Oil pressure at all times may be observed on an indicator located on the control panel of the airplane.

FUEL SYSTEM

The fuel system (figure 128) contains the following:

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1. Fuel filter.
2. Fuel pump.
3. Main engine fuel control.
4. Starting fuel control.
5. Drip valve.
6. Drain manifold and drain valve.
7. Fuel manifold and fuel nozzles.
8. Check valve.

The drain manifold and drain valve are connected to the lower combustion chambers. This unit drains the fuel when the engine is shut down, in order to avoid accumulation in the combustion chambers. The fuel manifold directs fuel to the nozzles. Equal distribution of fuel in all 14 combustion chambers is provided through the fuel nozzle in each chamber.

WATER–ALCOHOL SYSTEM

In order to improve the thrust rating at low altitudes, the J33–A–8 and J33–A–23 engines include water-alcohol injection equipment for the purpose of injecting a water-alcohol mixture into the compressor air inlet.

A water-alcohol injection manifold is mounted on the front truss ring, located around the front compressor inlet area. Fourteen nozzles, located in the manifold, spray the water-alcohol mixture into the front side of the compressor. Fourteen branch tubes, leading from the manifold back over the diffuser, spray the mixture through nozzles into the rear side of the compressor.

ELECTRICAL SYSTEM

The electrical system on late-model engines consists of a starter, generator, ignition harness with radio noise filter and condenser, two shielded high-tension leads and coil assemblies, and two ignition plugs. Figure 129 is a schematic diagram of the electrical system, as mounted on the engine. A main connector bracket assembly is mounted on the tachometer generator mounting adapter. Leads are provided from the connector to the tachometer generator and the generator. Additional leads are supplied from the connector for use with an

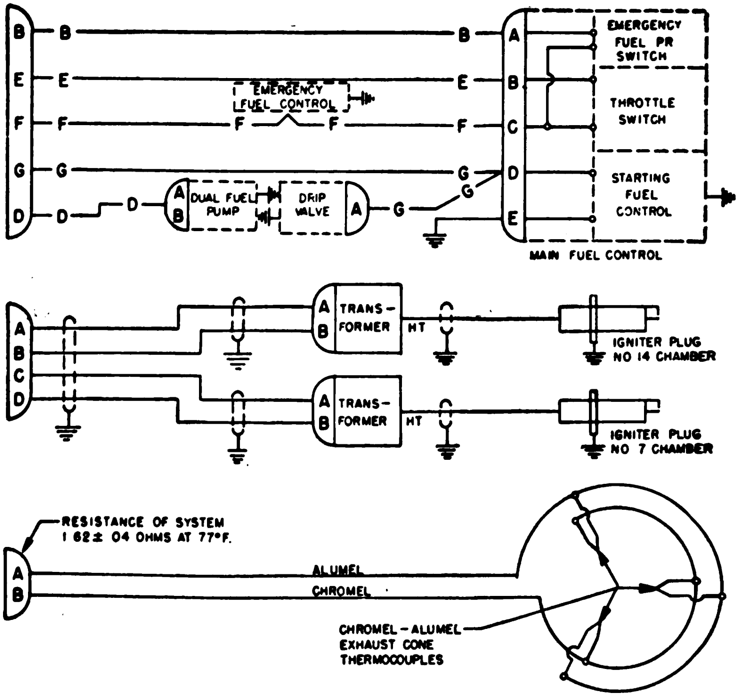


Figure 129.—Wiring diagram of electrical system.

oil thermostat and oil heater. There is an unshielded low-tension lead secured by three clamps which leads from the main connector bracket to the noise filter. The noise filter and ignition coils are mounted on the front truss ring mounting studs of the compressor casing. The coils and filter are connected together by low-tension shielded leads. From each coil, a shielded high-tension lead connects to each ignition plug.

QUIZ

1. What is the type of air compressor employed in the J33 engine?
2. Is the main fuel pump in the J33 of the constant displacement, or of the variable displacement type?
3. Where is the accessory drive assembly mounted on the J33?
4. What is the function of the drip valve?
5. Does the J33 use the wet sump, or the dry sump lubrication system?
6. How many combustion chambers does the J33 employ?
7. What is the purpose of the water-alcohol injection system found in the J33–A-8 and J33–A-23 engines?
8. Where is the water-alcohol spray introduced into the engine?

CHAPTER 13

J34 TURBO-JET ENGINE

The Westinghouse J34 turbo-jet engine is specifically designed for jet propulsion of aircraft. This engine consists essentially of an axial flow, eleven-stage compressor; a double fuel manifold; a double annular combustion chamber; a two-stage turbine; and a fixed position exhaust nozzle. Figures 130 and 131 show the bottom and cutaway views, respectively, of the J34–WE–22 engine.

The engine rotor, which includes the rotors of the turbine and compressor, is the only major moving part. It is supported on three anti-friction bearings. The No. 1 bearing carries the net thrust of the compressor and turbine.

The lubrication system is entirely self-contained on the engine except for the oil reservoir. The accessories, mounted on the gearbox, consist of a combined fuel pump and all-speed governor, an emergency fuel pump, and a lubricating fuel pump. These are driven, through suitable reduction gearing, by the shaft of the main engine rotor. Additional mounting pads on the gearbox provide for engine-driven aircraft accessories.

This engine does not require a warm-up when starting. When running, only one adjustable control is required. This is the throttle lever, which is linked to the all-speed governor. This governor controls the fuel flow to the fuel nozzles so as to maintain approximately constant engine speed corresponding to any throttle setting for all flight conditions.

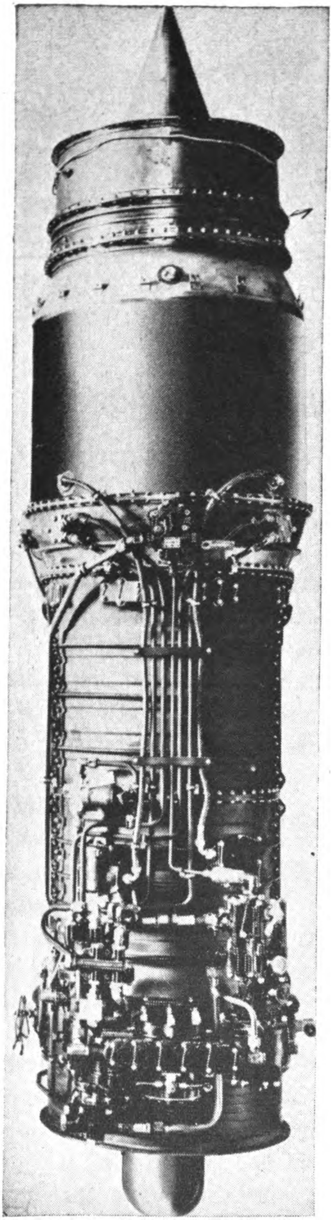


Figure 130.—Bottom view of J34–WE–22 engine.

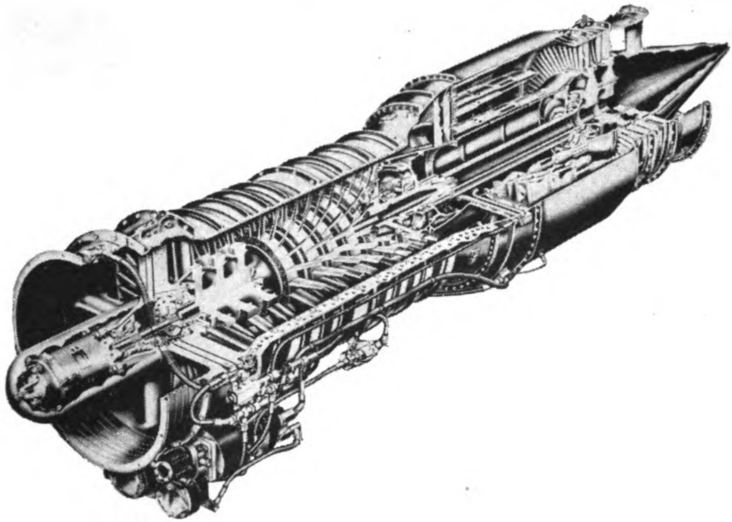


Figure 131.—J34–WE–22 engine cutaway.

In engine operation, moving air enters the front end through the oil cooler and passes through the No. 1 bearing support. Here the inlet guide vanes direct the stream into the axial flow compressor. And here the pressure is increased and the air directed into the combustion chamber at an increased pressure of approximately four atmospheres.

Fuel at high pressure is supplied to the fuel manifolds and atomized by the fuel nozzles which spray it into the combustion chamber. Combustion is accomplished here as the atomized fuel mixes with the pressurized air from the compressor. The hot gases are directed through the turbine nozzles against the turbine blades. A part of the energy of the gases rotates the turbine which provides the mechanical power to drive the compressor and the accessories. The gases leave the turbine with a high velocity and are expelled through the exhaust nozzle.

OIL COOLER

The oil cooler is mounted on the forward flange of the No. 1 bearing support and is connected in the oil line between the

relief valve and the check valve. It is fabricated from rectangular-sectioned aluminum tubing, spirally wound between two end flanges to form a cylinder. Two bosses are provided for oil inlet and outlet connections.

The purpose of the cooler is to reduce the temperature of the hot oil from the bearings for recirculation. Since the cooler acts as an inlet air duct, cooling effect occurs whenever the engine is operating. The forward flange of the cooler is designed for attachment to the aircraft inlet air duct.

NO. 1 BEARING SUPPORT

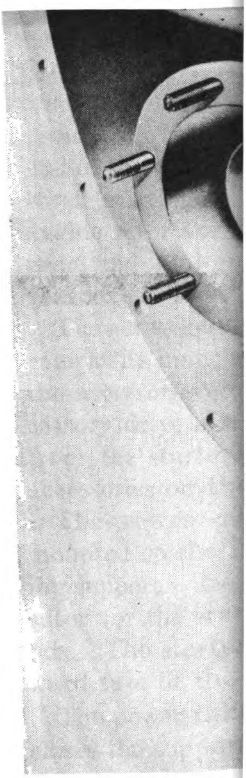
The main components of the No. 1 bearing support assembly are the accessory gearbox drive shaft, clutch shaft, compressor inlet guide vanes assembly, housing casting, and the power take-off gearbox. Figure 132 is a cutaway view of the No. 1 bearing support.

The cast magnesium housing has an inner ring and an outer ring connected by four integral radial struts. These struts are numbered from 1 to 4, inclusive, in a counterclockwise direction, beginning with the bottom strut. A pad is cast on the bottom of the housing for mounting the accessory gearbox. The oil cooler is mounted on the forward flange of the outer ring while the compressor housing is attached to the rear flange.

The power take-off gearbox is mounted on the forward face of the inner ring which also provides spring clips and a pin for positioning the starting motor cowl. A radial passage of the No. 3 strut connects with an inclined passage to the rear face of the inner ring to vent the No. 1 bearing to the atmosphere.

The forward radial passage through the No. 4 strut acts as the air passage of a pressure rake for compressor inlet total air pressure. Twenty-two small holes are drilled in the leading edge of the strut to connect with the radial passage. A tee-fitting in the outer end of the radial passage connects with the lines to the governor and to the pilot's cockpit. The rear radial passage houses the starter cable.

The forward radial passage in the No. 1 strut acts as an oil drain passage from the interior of the inner ring to the gear-



1. Compr
   rake.
2. Engine
3. Duplex
4. Pinion
5. Power
6. Air ver

box mounting pad. The rear radial passage houses the accessory gearbox drive shaft.

The forward radial passage through the No. 2 strut conducts lube oil to a spray fitting for both the No. 1 bearing and the power take-off gearbox. The rear radial passage accommodates the leads of the No. 1 bearing thermocouple.

The NO. 1 BEARING is attached to the rear of the inner ring. This single-row ball bearing is assembled on the front end of the compressor rotor.

The CLUTCH SHAFT is externally splined at its rear end to enter the spline flange attached to the forward end of the compressor rotor. Another external spline near the middle connects the shaft with the internal spline in the power take-off pinion. A three-tooth clutch jaw is machined on the forward end of the clutch shaft and engages the jaw teeth on the starter when starting. This clutch shaft transmits power from the engine rotor (or from the starter) through the power take-off gear and pinion to drive the accessories mounted on the gearbox.

The ACCESSORY DRIVE SHAFT is splined into the power take-off gear at its inner end, and into the spline coupling in the end of the accessories gearbox input shaft at its outer end. This accessory drive shaft transmits power from the engine rotor (or from the starter) through the gear and pinion to drive the accessories on the gearbox.

The POWER TAKE-OFF GEARBOX, shown in figure 132, is mounted on the front face of the inner ring of the No. 1 bearing support. Its function is to transmit power from the engine rotor (or the starter) to the accessories mounted on the gearbox. The starter is mounted on a pad machined on the forward face of the power take-off gearbox.

The power take-off gearbox consists of a housing which encloses the supporting bearing assemblies of the power take-off gear and pinion. The power take-off gear is supported by a duplex ball bearing in the lower portion of the gearbox, and a roller bearing supports the lower end of the gear. The power take-off pinion is supported by a duplex ball bearing on the forward end of the pinion shaft, and a roller bearing in the after end of the bearing housing.

The axial flow compressor consists of a compressor rotor and a compressor housing.

The major parts of the rotor assembly, shown in figure 133, are a shaft (14), sleeve (8), eleventh-stage disc (23), blades (5), and extension shaft (30). The No. 1 bearing (7) is included in the diagram to show the spline flange (2) through which the clutch shaft is connected to the compressor rotor. The No. 2 bearing (28) is also included. The steel sleeve (8) is shrunk on the aluminum shaft (14) to form the journal for the No. 1 bearing assembly. The steel eleventh-stage disc (23) is bolted to the after end of the shaft (14). The steel extension shaft (30) is bolted to the disc (23). The disc (23), the extension shaft (30) and rotor (14) have spigot fits for accurate alignment with each other. The blades (5) are pressed and locked into slots in the discs. The after end of the extension shaft is tapered to mate with the tapered hole in the forward end of the turbine shaft, and the end is threaded for the connecting locknut. Forward of the taper the extension shaft is externally splined for the coupling sleeve. Seal lands (15) are formed on the sides of each disc for close clearance with the seal strips in the inner shrouds of the vanes assemblies. Balancing rings (12) and (22), on the first and eleventh-stage discs, are machined in balancing the compressor rotor assembly.

The HOUSING (fig. 134) consists essentially of a cylinder with 12 vane assemblies fitted into internal grooves in the housing. The vane assemblies are located to alternate with the blade rows of the rotor. Each vane assembly is made in two pieces, and each half is secured in the housing by retaining screws. To facilitate assembly, the housing is also made in four sections—the upper inlet, lower inlet, upper outlet, and lower outlet, bolted together at their radial and horizontal flanges. The annular area (occupied by the blading of the housing and rotor) decreases rearward to provide greater compression. Aft of the blading, the housing becomes part of the outer wall of the compressor diffuser section. At this point, the annular area is increased to make a well-rounded entrance to the combustion chamber diffuser.

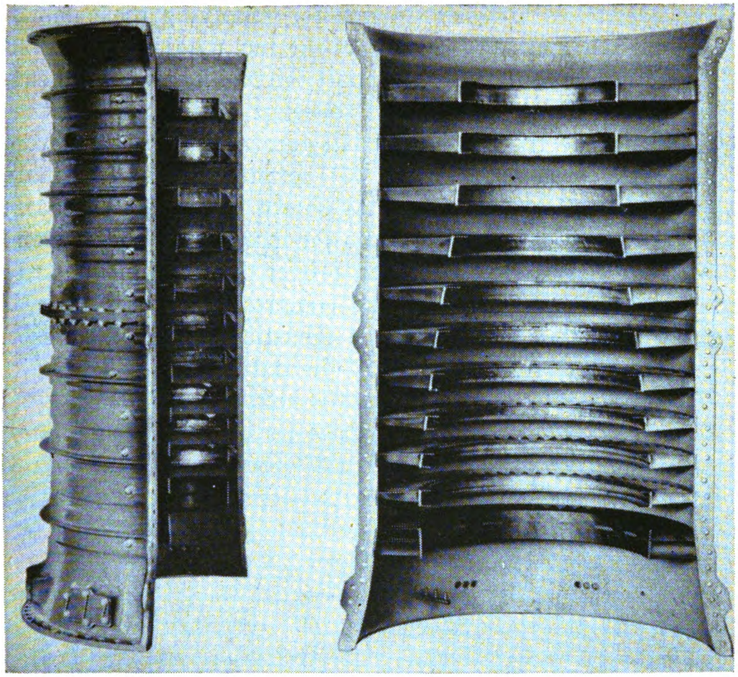


Figure 134.—Compressor housing.

COMBUSTION CHAMBER SECTION

The combustion chamber section is the portion of the engine between the compressor and the turbine. Its primary functions are (1) to mix fuel with air from the compressor in the proper proportion for good combustion, (2) to burn this mixture, and (3) to cool the hot products of combustion to a temperature which the turbine blade material will withstand under operating conditions. Its secondary functions are (1) to support the No. 2 and No. 3 bearing housings, (2) to provide the main engine supporting trunnions, and (3) to house the oil and scavenge tubing and thermocouple leads for the number 2 and number 3 bearings.

The functions of the combustion chamber DIFFUSER are (1) to diffuse the air from the compressor and divide it into

three concentric annular streams for supplying the combustion chamber liner, (2) to support the fuel manifold rings and their 60 fuel nozzles, (3) to support the No. 2 and No. 3 bearings, (4) to house the oil and scavenge tubing and thermocouple leads of these bearings and partly insulate them from combustion temperature, and (5) to provide the two main engine supporting trunnions. As shown in figure 135, coarse wire mesh screens are clamped on the manifold at the rear end of the diffuser section to aid in proper distribution of air to the combustion chamber. The compressor diffuser cone is attached to the front of the combustion chamber diffuser. Figure 136 is a cutaway view of the diffuser.

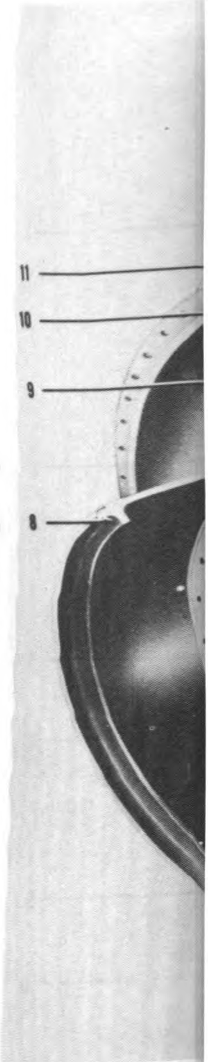
The combustion chamber LINER is bolted to lugs on the fuel manifold. Twenty-four fuel nozzles are screwed into the inner fuel manifold ring and 36 into the outer ring. The nozzles project into the two concentric sections of the combustion chamber liner where the fuel from the nozzles and air from the compressor are mixed, ignited, burned, and cooled.

The liner is perforated with holes increasing in size toward the rear to give proper air distribution. Primary air enters the liner through the up-stream holes to initiate the combustion process, while secondary air enters through the down-stream holes to reduce the temperature of the hot gases.

The combustion chamber HOUSING is a steel cylinder bolted to the rear flange of the diffuser. This cylinder is the outer cover of the combustion chamber and extends aft to the turbine housing. Two drilled and tapped bosses for the spark plugs are located near the front of the housing.

TURBINE SECTION

Mechanical power for driving the compressor rotor and the engine driven accessories is supplied by the axial flow, two-stage turbine. Each stage consists of a turbine nozzle assembly, followed by a rotating blade assembly. The hot gases from the combustion chamber flow through the first-stage turbine nozzle assembly and are directed against the rotating blades of the first-stage rotating turbine disc. The gases then pass through the second-stage turbine nozzle assembly and are



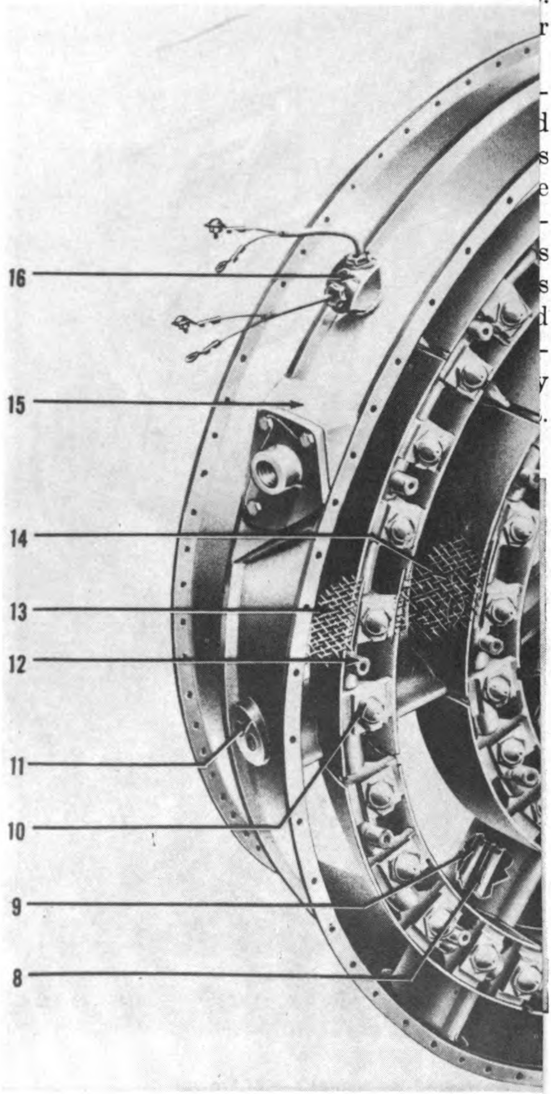
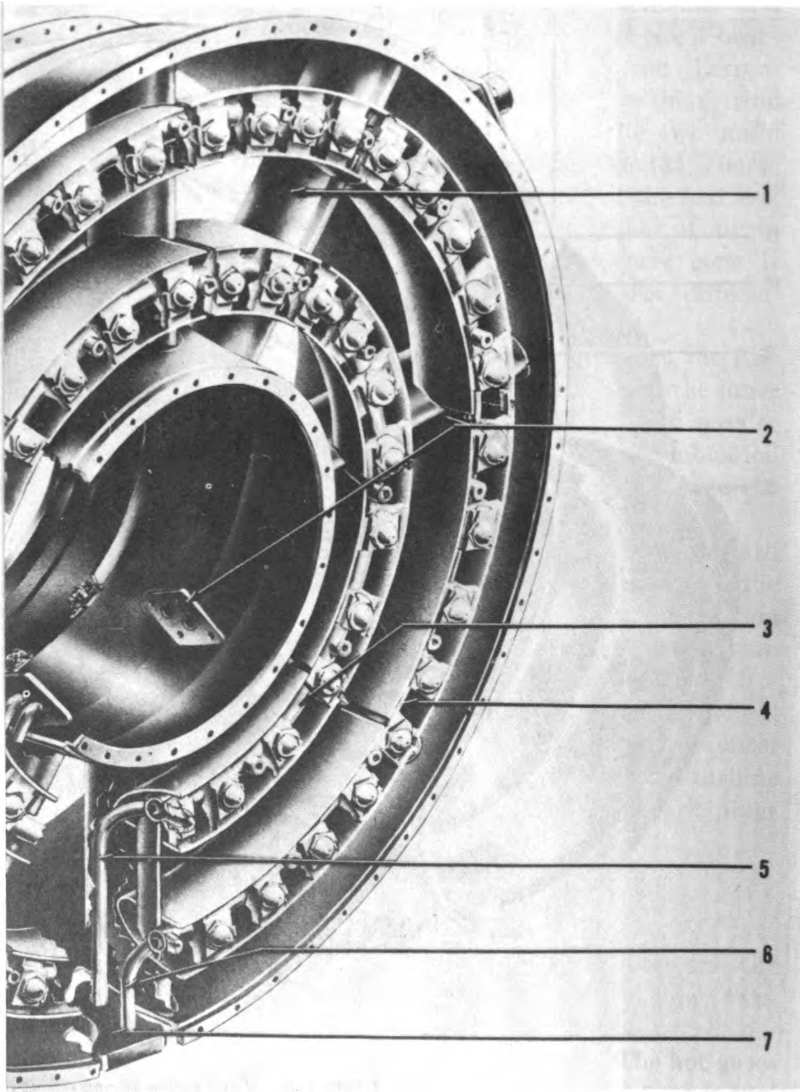


Figure 136.—

1. Strut.
2. Scavenge flange.
3. Outer manifold.
4. Inner manifold.
5. Fuel supply
6. Fuel supply
7. Dump valve
8. Scavenge tub



-Combustion chamber diffuser cutaway.

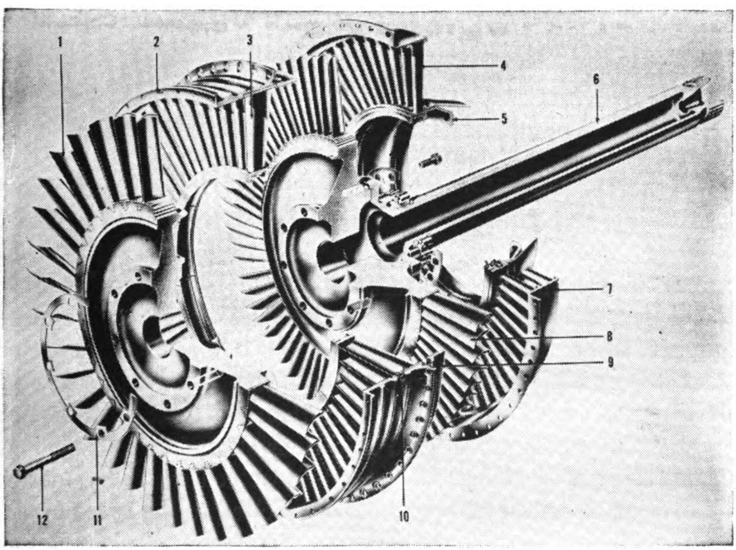
tube.
tube.
boss.
›e.

9. Scavenge tube.
10. Fuel nozzle.
11. Oil supply boss.
12. Liner mounting lug.

13. Outer screen.
14. Inner screen.
15. Mounting trunnion.
16. Thermocouple boss.

directed against the blades of the second-stage rotating disc. The gases give up part of their energy to drive the turbine rotor and then flow into the exhaust section.

The turbine rotor (fig. 137) is made up of a steel shaft, first-stage disc and second-stage disc, accurately fitted and bolted together. High-temperature alloy blades are locked in grooves broached in the periphery of the discs. The entire turbine rotor is both statically and dynamically balanced. The forward end of the turbine shaft has a tapered hole which mates with the tapered end of the compressor stub shaft. The ends of the turbine shaft and the stub shaft are externally splined to mate with a splined coupling sleeve which carries the torsion load between the compressor and turbine rotors. They are secured together by a locknut, on the end of the stub shaft.



1. Second stage disc.
2. Turbine housing.
3. Second stage turbine nozzle.
4. First stage turbine nozzle.
5. Support.
6. Turbine shaft.
7. Outer support.
8. First stage disc.
9. Spacer ring.
10. Retaining bolt.
11. Tabring.
12. Disc bolt.

Figure 137.—Turbine section cutaway.

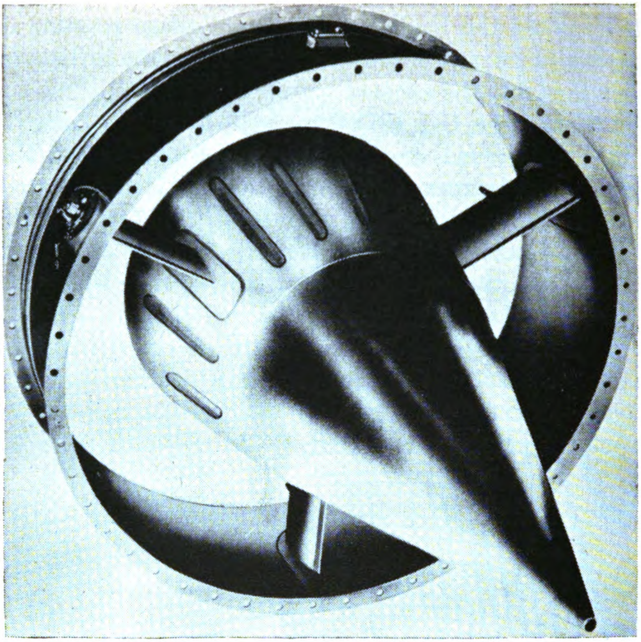


Figure 138.—Exhaust collector and cone.

The stator element of the turbine is made up of the first and second nozzle vane assembly, each housed in the combustion chamber immediately forward of its rotor disc. The nozzle vanes are of high-temperature alloy. The first-stage turbine nozzle vanes are loosely fitted in their shrouds, while the second-stage vanes are welded into their shrouds.

The fixed-type exhaust collector is a welded assembly made of corrosion-resistant sheet steel and is bolted to the rear flange of the turbine housing. It consists of an inner cone and an outer casing connected by three radial hollow struts, as shown in figure 138.

The annular area between the cone and casing increases rearward. The exhaust gases from the turbine pass through this area and gradually form a solid jet at the optimum velocity to produce maximum thrust for the propulsion of the aircraft.

Three bosses on the outer casing, one opposite the end of each strut, provide for installation of the turbine outlet thermocouples. Another boss on the outer casing permits the installation of a pressure rake, when required for testing.

ENGINE ROTOR AND MAIN BEARINGS

The engine rotor assembly is made up of the compressor rotor and turbine rotor, individually balanced and coupled by an internally splined coupling sleeve and a locknut. The rotor is coupled through the clutch drive shaft to the accessory drive pinion.

The engine rotor is supported on three bearings, each fitted in a spherical mount to permit self-alignment of the engine rotor regardless of vibration and a certain amount of distortion or warping of the airframe.

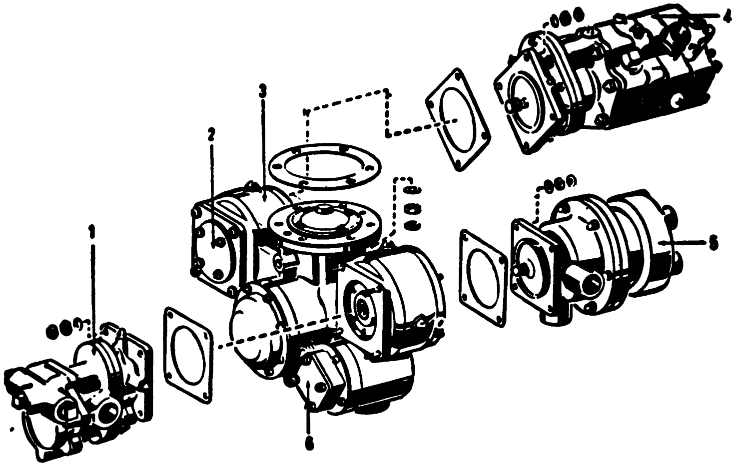
The No. 1 bearing is mounted in the rear of the front bearing support. It is a single-row ball bearing taking both thrust and radial loads. It is built to continue functioning even though the ball bearing should fail.

The No. 2 bearing and housing assembly is supported by the support ring on the front of the combustion chamber diffuser. It is a single-row uncrowned roller bearing carrying radial loads only.

The No. 3 bearing and housing assembly is bolted to the support on the first-stage turbine nozzle assembly which is secured in the rear of the combustion chamber housing. The bearing itself is identical with the No. 2 bearing, and the housing is similar except that the shape is modified for attachment to its support.

ACCESSORY GEARBOX

The accessory gearbox (see fig. 139) is a magnesium alloy T-shaped casting which houses and supports the accessory drive gear trains. Mounting pads are cast and machined on this casting for the engine driven accessories. On the rear are the pads for the oil and scavenge pump, the governor, and the generator. On the front face of the gearbox is a mounting pad for the emergency fuel pump and additional pads for a hy-



1. Emergency fuel pump.
2. Hyd or vac pump drive.
3. Accessory gearbox.
4. Fuel control.
5. Oil and scavenge pump.
6. Tach generator drive.

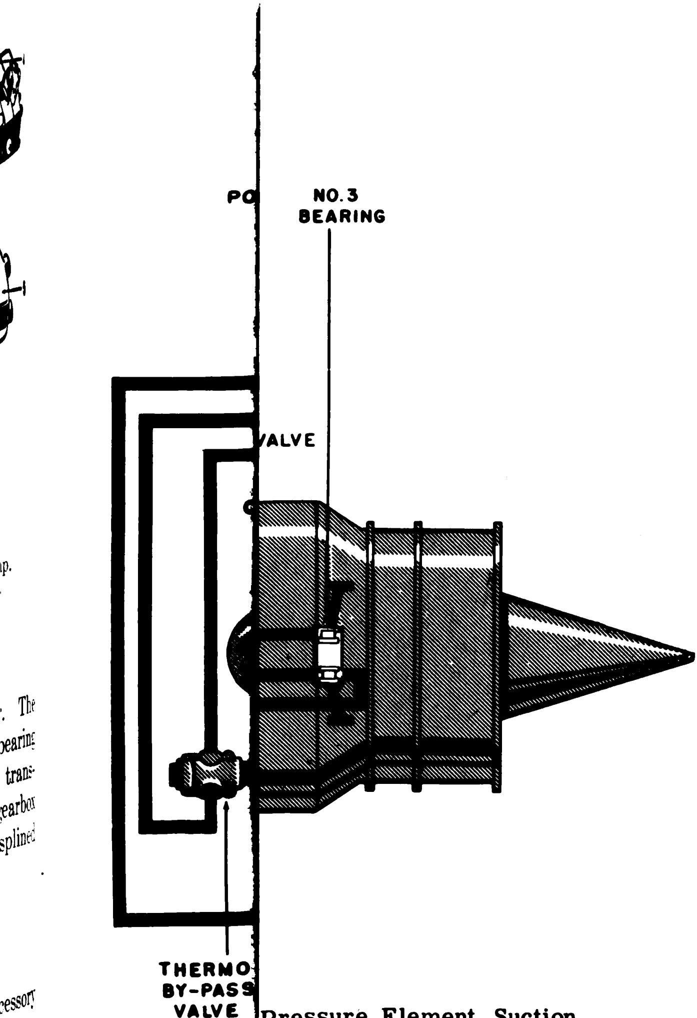
Figure 139.—Gearbox and attached accessories.

draulic or vacuum pump and for a tachometer generator. The gearbox is attached to the mounting pad on the No. 1 bearing support. Mechanical power from the engine rotor is transmitted to the gearbox through the power take-off gearbox which is connected to the accessory gearbox by the splined accessory drive shaft in the No. 1 bearing support.

LUBRICATION SYSTEM

The circulating oil system (fig. 140) lubricates the accessory gearbox, the power take-off gearbox, and the three main bearings. Oil is drawn from a reservoir by the lube element of the six-element oil and scavenge pump. From the pump, high-pressure oil flows through a filter and a relief valve to the oil cooler. The relief valve protects the system by returning a portion of the oil to the pump intake when excessive pressure occurs.

After circulating through the cooler the oil passes through a check valve to a cross fitting. Lines from the cross fitting



Pressure Element Suction
High Pressure Oil
Scavenge Oil
Scavenge Discharge

(Face p. 272)

carry the oil to the three bearings and the accessory gearbox. The power take-off gearbox receives its lubrication through passages in the No. 1 bearing support.

The five scavenge elements of the pump drain the oil from the front and rear of both the No. 2 and No. 3 bearings, and from the gearbox. Oil scavenged from the accessory gearbox includes the oil from the No. 1 bearing and the power take-off gearbox.

The oil and scavenge pump consists of six gerotor units. The lubrication gerotor has its own intake and discharge ports with pipe connections on the sides of the pump body. Each scavenge element has a separate intake but all discharge into a common port with pipe connections on the end of the pump body. Each scavenge element has sufficient capacity to handle the entire flow of the lubrication pump, and is not affected by the operation of the other elements.

The OIL FILTER is a replaceable element type, designed to remove foreign matter from the oil in the lubrication system. It is connected in the line between the oil pump and the relief valve and is mounted on a bracket attached to the compressor housing.

When the filter element becomes clogged by foreign particles in the oil stream, the two relief valves incorporated in the head of the filter assembly open at a maximum pressure differential of 50 p.s.i. and bypass the oil through the head, thereby insuring oil flow to the bearings even if the filter element is clogged.

The HIGH PRESSURE RELIEF VALVE is connected in the line between the filter and the oil cooler. Its function is to limit the pressure of the oil delivered to the bearings. It is a spring-loaded piston valve, set so that it will begin to open at a pressure of 150 p.s.i., and return part of the oil to the pump inlet.

The CHECK VALVE is connected in the line between the oil cooler and the cross fitting. The function of the check valve is to prevent oil from draining from the lines after the engine is shut down and to eliminate the necessity of priming the oil system before each start.

The METERING PLUG ASSEMBLY consists of a body, three metering plugs, a retainer, and an end fitting. The metering plugs are arranged in series, with their orifices staggered to

provide a pressure drop. Lubricating oil for the outer ball bearings and roller bearings of the accessory drive shaft passes through the metering plug.

FUEL SYSTEM

The fuel system (fig. 141) includes an all-speed governor, emergency fuel pump, fuel filter, fuel dump valve, 2 fuel manifolds and 60 fuel nozzles. The governor assembly includes the primary fuel pump, a pump selector valve, and the governing mechanism.

In operation, fuel is drawn from a reservoir by a booster pump and delivered, at a pressure of about 15 p.s.i., through a filter to the inlets of the primary fuel pump and the emergency fuel pump.

Fuel at high pressure is discharged from the governor and flows to the dump valve. Tubing inside the engine conducts the flow to the inner and outer rings of the fuel manifold in the combustion chamber diffuser. Here it is sprayed from the fuel nozzles and mixed with pressurized air from the compressor to burn in the liner of the combustion chamber.

When the engine is shut down, the drop in pump discharge pressure operates the dump valve which shuts off all flow from the governor and drains residual fuel from the manifolds. This results in a clean cutoff of the combustion.

To sustain operation in the event of primary fuel pump failure, the emergency fuel pump automatically supplies fuel to the governor by the action of the pump selector valve.

The purpose of the governor is to maintain a relatively constant engine speed for a fixed throttle setting regardless of engine operating conditions. The governor includes in a single unit, the primary fuel pump, the pump selector valve, and the control mechanism. The unit is mounted on the accessory drive gearbox and is positively coupled to the engine rotor.

The EMERGENCY FUEL PUMP is mounted on its own pad on the accessory drive gearbox and runs at the same speed and has the same capacity as the primary pump. Its purpose is to sustain the operation of the engine in the event of failure of the primary fuel pump.

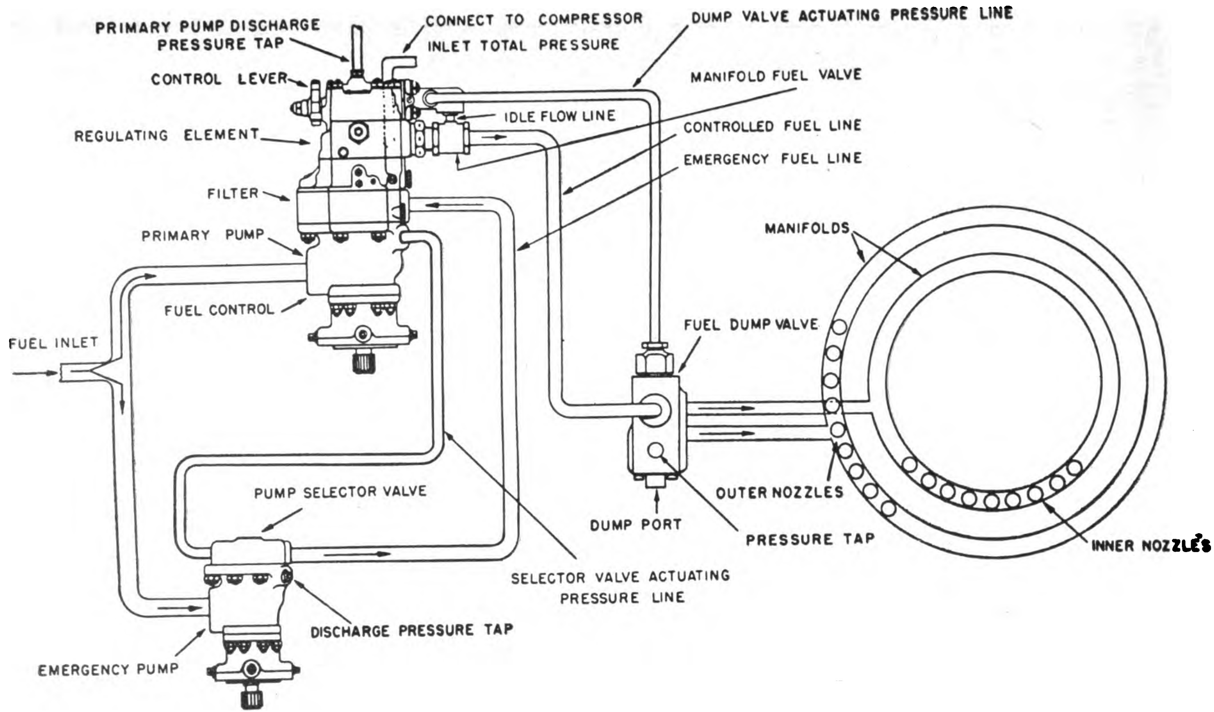


Figure 141.—Fuel system schematic.

The FUEL FILTER is located in the actuating pressure line from the governor to the dump valve. The filter assembly consists of a case and a head, containing a filter element and a spring-loaded relief valve.

The relief valve keeps the relief port shut while fuel is able to pass through the filter. When the filter element becomes clogged, the increased pressure on the valve opens the relief port and bypasses the fuel around the element to the dump valve actuating line.

The FUEL DUMP VALVE is designed to clear the fuel manifolds of residual fuel when the engine is shut down. It is located in the fuel supply line between the governor and the fuel manifolds and is mounted, with an adapter, on the bottom of the combustion chamber diffuser.

The inner and outer FUEL MANIFOLD RINGS are mounted concentrically in, and welded to, radial brackets. The radial brackets, in turn, are welded to the trailing edges of the radial struts of the combustion chamber diffuser. The manifold rings are concentric with, and normal to, the axis of the engine.

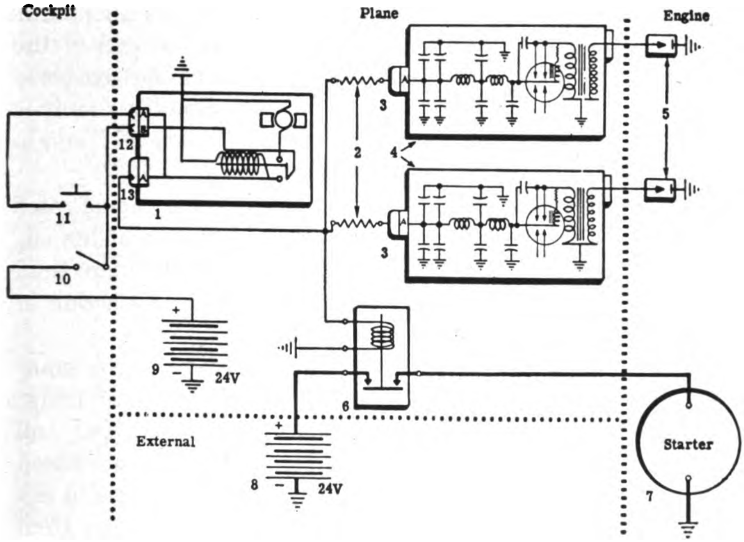
Each manifold ring is a circular header of steel tubing with equally spaced, tapped bosses for the fuel nozzles and tapped mounting lugs for the combustion chamber liner.

Each manifold ring is streamlined by a segmented fairing welded to the ring. This arrangement makes for a smooth airflow and, at the same time, tends to provide proper distribution of air to the three annular passages through the combustion chamber.

After passing through the dump valve, fuel flows through separate tubes to the inner and outer manifold rings and is then sprayed into the combustion chamber by the atomizing type FUEL NOZZLES. These nozzles discharge fuel into the combustion chamber where it burns as it mixes with compressed air. There are 36 nozzles in the outer manifold ring and 24 in the inner ring. Each nozzle has a nominal capacity of 7.5 gallons per hour at a pressure drop of 100 p.s.i.

ELECTRICAL SYSTEM

The sole function of the electrical system is to start the engine. Once the engine is operating, the electrical system is not involved in sustaining operation or in stopping the engine.



1. Control timer.
2. Resistors.
3. Connector (AN-3106-10S-2S).
4. Ignition coils.
5. Spark plugs.
6. Starter contractor.
7. Starter.
8. External power source.
9. Plane power source.
10. Master switch.
11. Starting switch.
12. Connector (AN3106-14S-9P).
13. Connector (AN3106-14S-9S).

Figure 142.—Electrical system.

The electrical system (fig. 142) comprises the following components: one control timer switch, one control timer, two contactors, one starter, one 24-volt d.-c. battery, two ignition coils, two spark plugs, and one ram start switch.

The CONTROL TIMER SWITCH is a single-pole, single-throw, momentary-contact switch, located in the cockpit. Momentary closing of the starting switch initiates the starting cycle by energizing the control timer.

The function of the CONTROL TIMER is to close and maintain the electrical circuits to the starter motor and the ignition coils

for a period of approximately 30 seconds, thus allowing sufficient time for engine operation to become self-sustaining. Overheating of the starter motor is thus prevented by confining its operation to this short period.

The function of the STARTER SOLENOID CONTACTOR is to close the circuit to the starter motor when the coil of the solenoid is energized by action of the control timer. At the end of the 30-second starting cycle the coil of the solenoid is de-energized by action of the control timer and the starter motor circuit is broken. This unit comprises a 24-volt d.-c. solenoid and a set of heavy-duty 200-ampere contacts.

The function of the STARTER is to accelerate the engine rotor to a speed sufficient to give self-sustained operation of the engine. The starter motor operates for periods of not more than 30 seconds, operation being initiated and stopped by action of the control timer.

The starter comprises a 10-horsepower, 24-volt d.-c. compound wound motor; a 4 to 1 ratio, speed-reducing gear train; an adjustable torque-limiting clutch (friction disc type) and a three-tooth driving jaw. With 17 volts d.c. maintained across the starter motor terminals, the starter is capable of delivering a 35 lb.-ft. torque at an output speed of not less than 1,500 r.p.m.

The function of the IGNITION COILS is to provide the high voltage required for ignition. Their operation during the 30-second timing cycle is controlled by the control timer. Two coils are used in each engine. The coil primaries are wired in parallel and the high-tension output of each coil goes to its respective spark plug. The rating of each coil is 1.0 to 1.2 amperes at 24 volts d.c. Ignition coils are mounted upon and grounded to the compressor housing.

For RAM OR WINDMILL STARTS, the ignition system (including coils and spark plugs) may be operated without the starter, and with or without the control timer.

Two SPARK PLUGS ignite the fuel-air mixture in the combustion chamber during the 30-second starting cycle. The plugs are mounted near the bottom of the combustion chamber housing and protrude through the outer wall of the liner to place the spark in the annular stream of the fuel and air mixture.

QUIZ

1. Does the J34 employ an axial flow or a radial flow air compressor?
2. Explain the action of the electrical circuit using the following elements: control timer switch, control timer, starter solenoid contactor, starter, ignition coils, spark plugs.
3. Is the compressor housing on the J34 a one-piece, two-piece, or four-piece unit?
4. How many fuel manifold rings does the J34 employ?
5. Where are the fuel manifold rings located?

CHAPTER 14

J42 TURBO-JET ENGINE

The model J42–P–4 or J42–P–6 engine is a turbo-jet powerplant which employs a single-stage, double-sided, centrifugal compressor. This engine also uses a single-stage turbine and nine radially-arranged axial flow-type combustion chambers. Figures 143 and 144 show the left and rear view, respectively, of the J42 engine.

This model engine has three major sections (fig. 145) which are arranged from front to rear in this manner:

Accessory
Compressor and turbine
Exhaust

Except for the fuel system, the models J42–P–4 and J42–P–6 engines are basically the same. Fuel pumps on the J42–P–4 are mounted on adapters and are lubricated by adding oil to the fuel. The fuel pumps on the J42–P–6 engine are mounted directly on the accessory case and are lubricated by the fuel.

ACCESSORY SECTION

The accessory section of the J42 engines is comprised of the

accessory case, the case cover assembly, the various engine accessory drives, and a wet oil sump.

The ACCESSORY CASE (fig. 146) is mounted on the front bearing case assembly. It is a machined magnesium casting incorporating pads for mounting the various engine accessories, the oil pump, the oil sump, and a breather. A fuel filter and a fuel pressure and shut-off valve are also mounted on the case. Inside the case are housed the various drives. Cored passages and oil tubes are provided to supply lubrication and to drain oil from the case.

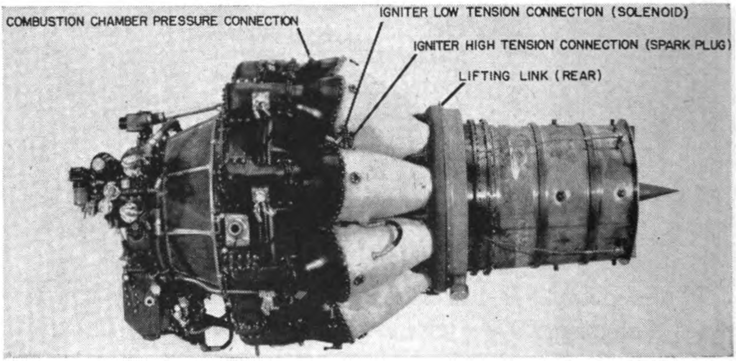


Figure 143.—Left side view of Model J42–P–6 engine.

The gear train of the accessory section provides DRIVES for the following units:

- Two fuel pumps
- Generator
- Starter
- Fuel control
- Auxiliary unit
- Power take-off
- Tachometer
- Auxiliary fuel booster pump

The reduction gearing inside the case provides suitable drive speeds for each accessory.

The WET OIL SUMP is mounted on the bottom of the accessory

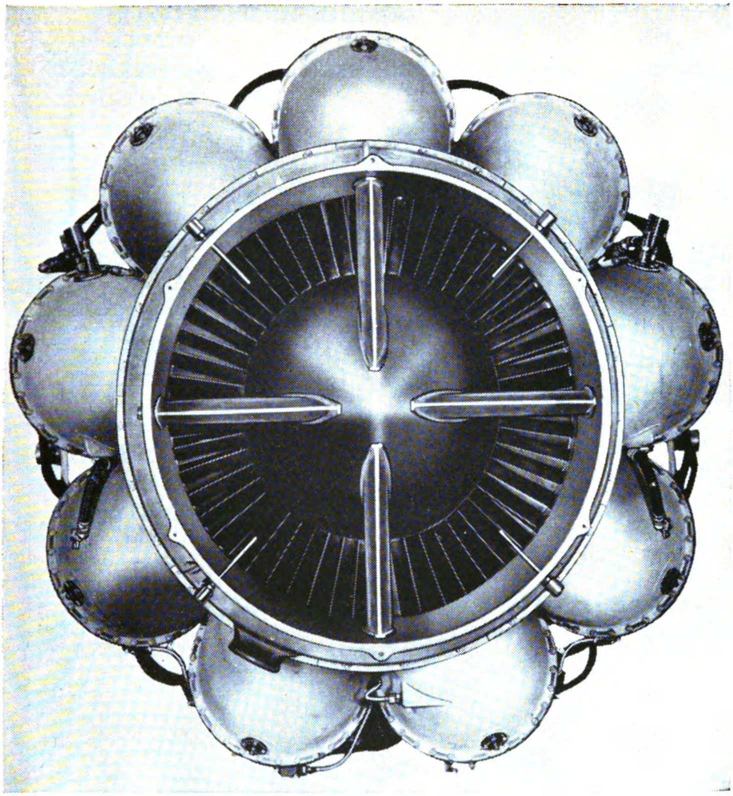


Figure 144.—Rear view of the J42 engine.

case. This unit encloses a dual oil pump, two pressure oil strainers, a scavenge oil strainer, and a de-aerator. Cored passages and oil tubes supply oil to, and drain oil from, the accessory case.

The COVER ASSEMBLY (fig. 147) supports the accessory drive shaftgear and the upper and lower accessory intermediate drive gears through ball bearings mounted in the cover. The accessory gear train is driven by the rotor assembly through the accessory drive shaftgear coupling which splines with the shaftgear and the rotor assembly compressor hub.

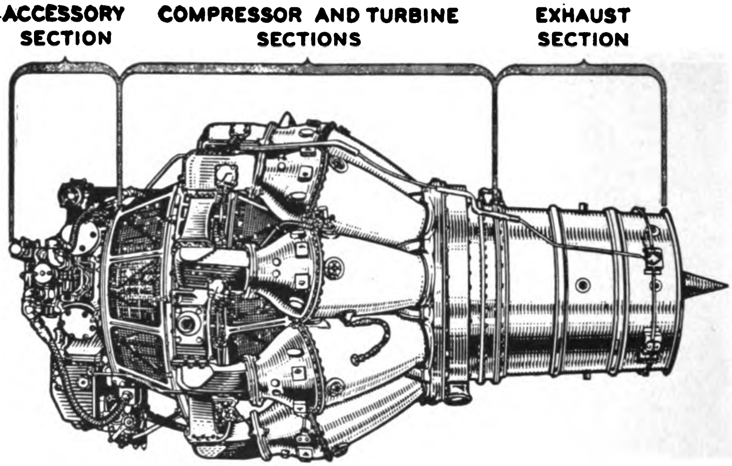


Figure 145.—Three major sections of the J42 turbo-jet engine.

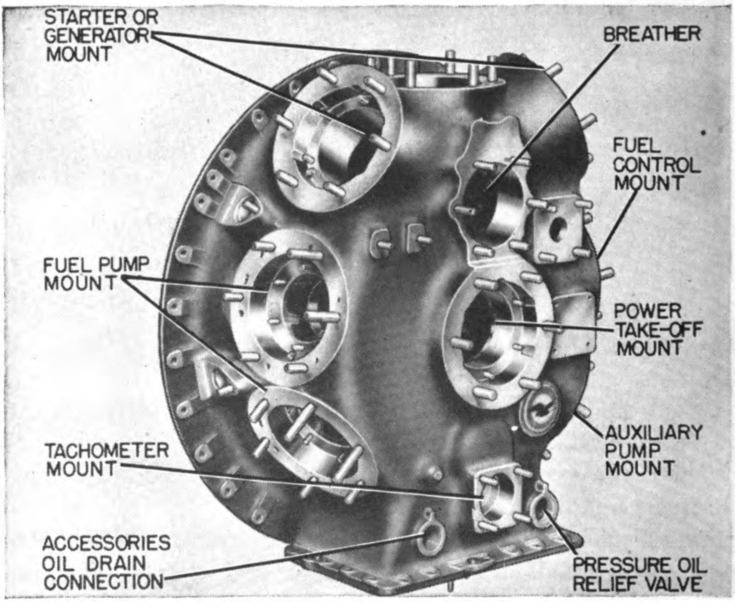


Figure 146.—Accessory case.

COMPRESSOR AND TURBINE SECTION

The compressor and turbine section is composed of the following assemblies:

- Front bearing case
- Front screen support
- Compressor case
- Rear screen support
- Center bearing case
- Rear bearing case
- Combustion chamber support
- Compressor rotor and turbine rotor balancing assemblies

The complete rotor assembly is supported at each end by a roller bearing, and at the center by a deep groove ball bearing. This latter ball bearing supports axial thrust and radial load.

A single-sided centrifugal cooling air impeller is mounted on the rear of the compressor shaft, forward of the center bearing. Just rear of the center bearing is the connecting coupling which allows for slight misalignment under running conditions.

Nine combustion chambers are equally spaced around the compressor and turbine section. These chambers converge rearward into the combustion chamber support assembly.

Shown in figure 148 is the front bearing and front bearing case assembly, which supports the accessory case and the compressor hub. The contour of the rear surface of the case forms an entrance for the air into the compressor. The thread-type oil seal at the rear of the bearing is pressurized by air from an external line connected to the compressor case to minimize oil leakage along the compressor hub. Oil tubes and fittings are mounted on the front surface of the case to provide oil flow to and from the bearing.

The front and rear screen support assemblies (figures 149 and 150) are bolted to the front and rear sides of the compressor case, respectively. They serve as an air entrance to the compressor and as a support for the front and center bearing cases. A wire mesh screen covers every support. This screen prevents the entry of foreign matter into the compressor.

The compressor front and rear inlet vane assemblies are supported, respectively, within the front and rear screen support

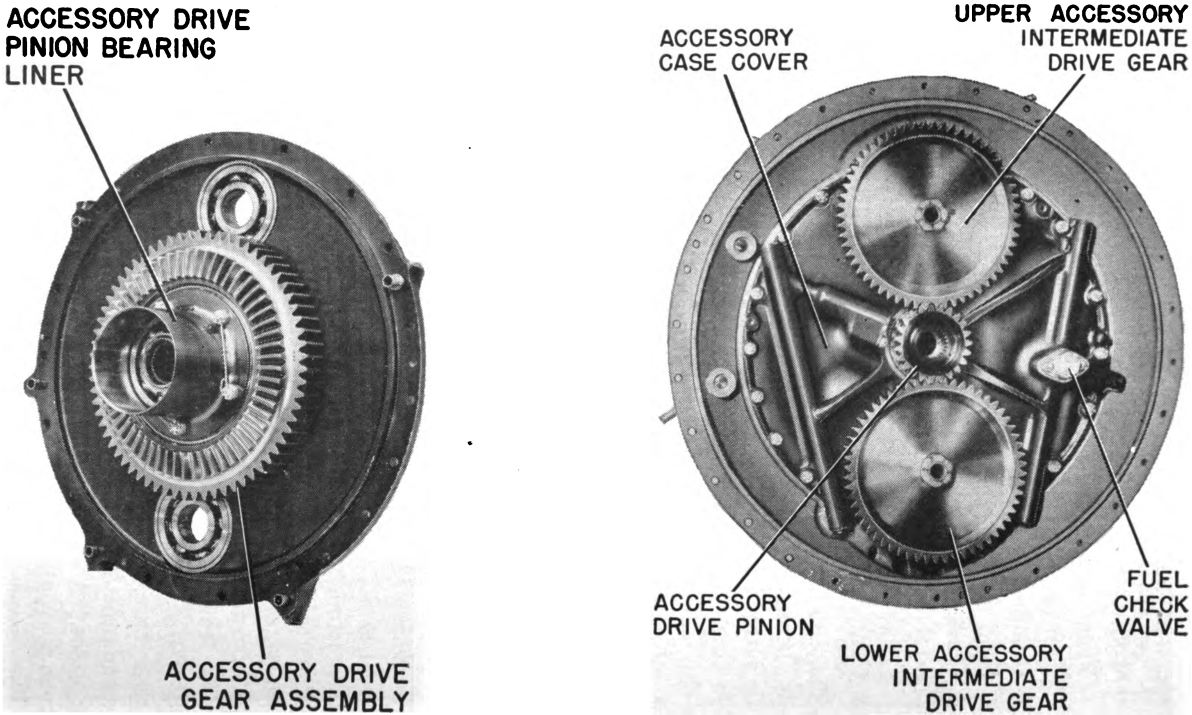


Figure 147.—Accessory case cover assembly.

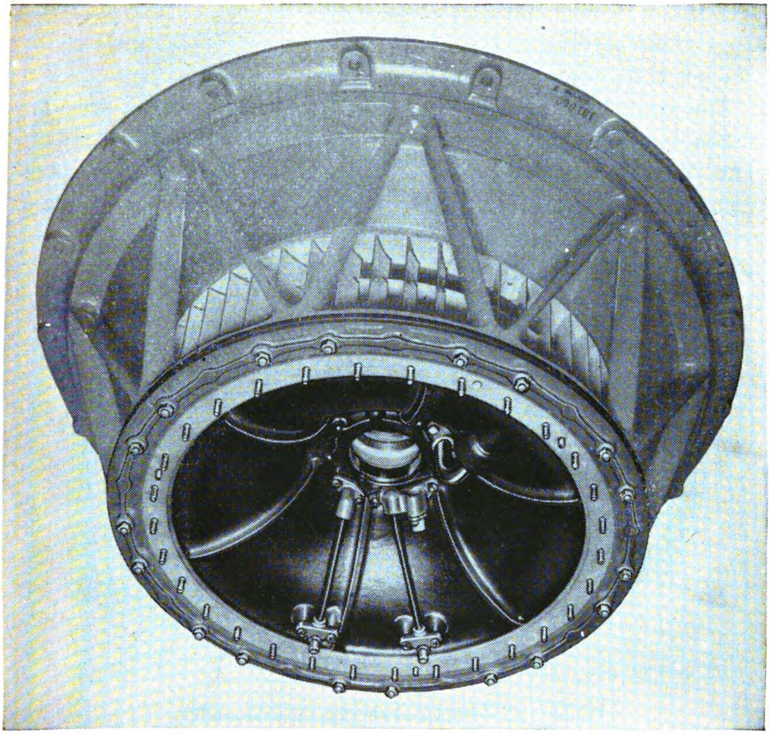


Figure 148.—Front bearing and front bearing case assembly.

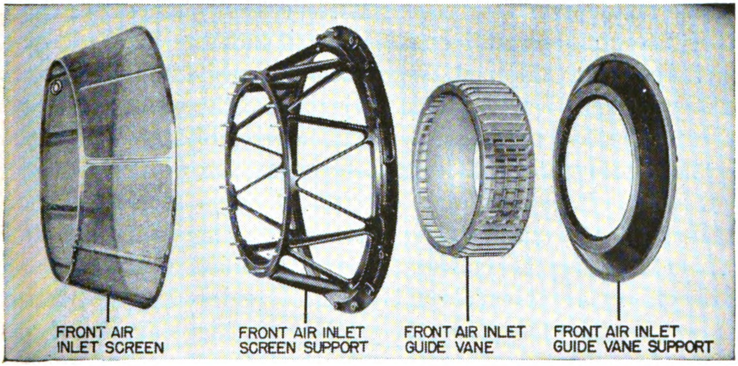


Figure 149.—Front screen support assemblies.

assemblies. The vanes provide a pre-swirl effect and distribute the air across the eye of the impeller before the air stream reaches the compressor.

The COMPRESSOR CASE consists of a front and rear section. When bolted together, the case houses the compressor rotor. The diffuser, located inside the rear case, has tapered face vanes. These insure abutment of the vane tips when the case sections are bolted together. Three engine mounting brackets and two lifting eyes are located on the periphery of the compressor rear case.

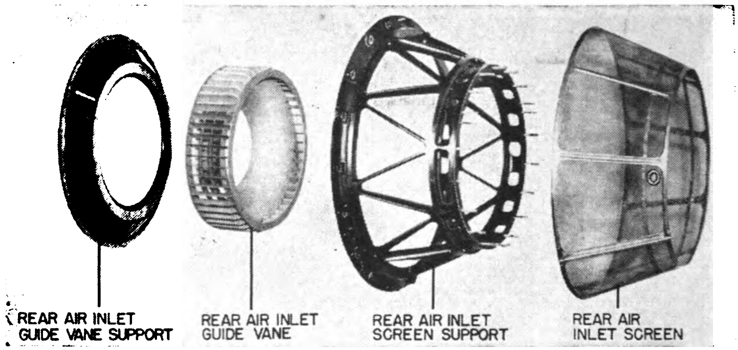


Figure 150.—Rear screen support assemblies.

INLET DUCTS which conduct the air to the combustion chambers are bolted to the facings of the nine air outlet ports located on the compressor rear case. Three cascade vanes, designed to reduce air pressure losses, are fitted into the bend of each inlet duct (fig. 151). A fuel nozzle assembly is mounted on each inlet duct. This nozzle projects into the cover and liner of its respective combustion chamber assembly.

The COMBUSTION CHAMBER ASSEMBLIES are of the straight flow type. Each assembly consists of three sections—inner section (liner), outer casing (combustion chamber), and the combustion chamber cover. The combustion chamber liner incorporates an assembly of flare, grid, and swirl type vanes. These vanes are fitted into the primary air inlet entrance of the liner cone. The combustion chamber cover is bolted to the combustion chamber to form a complete assembly.

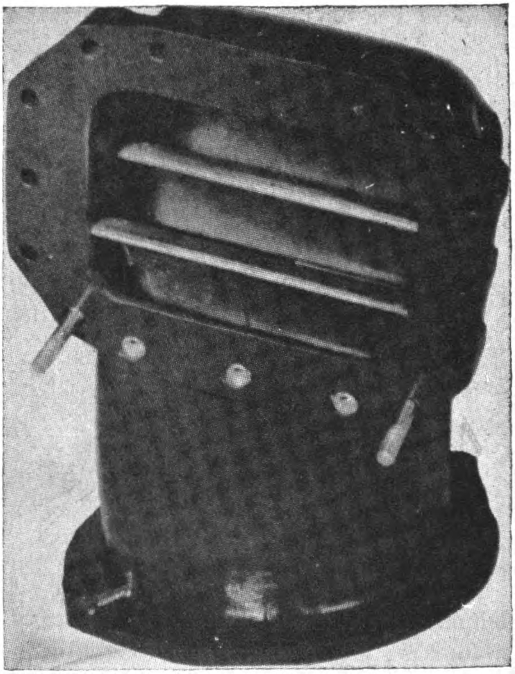


Figure 151.—Combustion chamber inlet ducts.

A spherical spacer is placed between the mating faces of the combustion chamber assembles and combustion chamber inlet ducts before they are bolted together. The discharge end of the chamber slides into the combustion chamber support. This allows axial expansion while forming a gastight slip connection. The chambers are connected by tubes. These tubes allow a pressure balance in adjacent chambers and serve as flame transfer tubes from the two chambers which contain the starting igniters.

An igniter incorporated in each of the No. 3 and No. 8 combustion chambers begins the combustion which rapidly progresses from chamber to chamber through the interconnecting tubes.

Combustion chambers Nos. 3 through 5, and 6 through 8, are interconnected by fuel drain lines. Unburned fuel in these

chambers will drain to the two bottom chambers (5 and 6) and into a collector which is emptied by siphoning action when the plane becomes airborne.

A fuel nozzle (figure 152) is supported in a hole in the dome of each combustion chamber liner. These nozzles are detachable from the combustion chamber inlet duct.

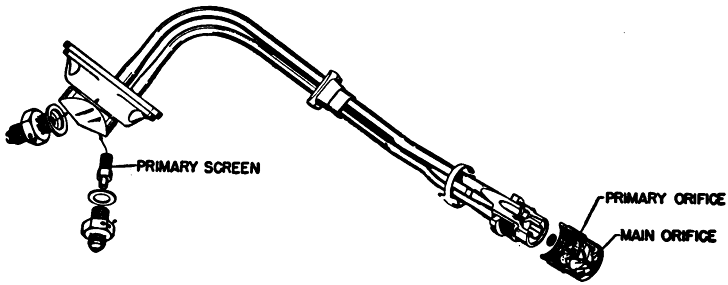


Figure 152.—Fuel nozzle.

Each fuel nozzle combines two stages of spray—primary and main. Fuel is supplied to the two stages by their respective fuel manifold. At low fuel flow, all the fuel is delivered to the primary atomizer of the fuel nozzle. At high fuel flow, the primary system continues as before but is supplemented by fuel from the main fuel manifold.

Each igniter (fig. 153) consists of a solenoid-operated low-pressure fuel atomizer and a spark plug.

The electrodes of the spark plug are exposed to the relatively cool air flowing between the combustion chamber liner and the combustion chamber, and are only exposed to high temperatures during the starting cycle while ignition is provided to ignite the fuel spray from the low pressure fuel atomizer. The atomizers are supplied with fuel from the fuel manifold.

The operation of the igniters begins when the aircraft starting equipment supplies current to the igniter system at the beginning of the starting cycle. The low-tension current is connected to the igniter solenoid valve, while the high-tension current from the ignition coils is fed to the spark plug center electrode. Thus, when the system is in operation the flame

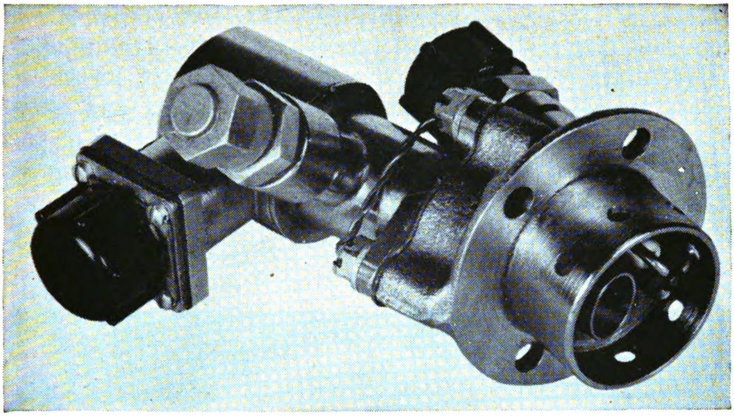


Figure 153.—Igniters.

igniter solenoid is energized, which opens the atomizer needle valve. The fuel under pressure from the booster pump is then discharged from the atomizer as fine spray and ignited by the spark plug.

The fuel being discharged from the fuel nozzles in the combustion chambers is, in turn, ignited by the flame from the igniter. Interconnector tubes between adjacent combustion chambers enable all the chambers to become ignited almost simultaneously. After the engine has been started, the current to the igniters is cut off. This allows the atomizer valve to close under spring pressure, thereby extinguishing the ignition flame.

The deep groove ball-type center bearing and bearing support are mounted in the CENTER BEARING CASE. The bearing is pressurized by air from the cooling impeller. Axial adjustment of the rotor assembly is controlled by a spacer located between the bearing support and the bearing case.

The REAR BEARING CASE consists of an inner and outer casing. It is bolted to the rear of the center bearing case. The roller-type rear bearing is mounted in the inner casing, and is cooled by pressurized air from the cooling impeller. The outer casing acts as a heat-shield.

The COMBUSTION CHAMBER SUPPORT (fig. 154) consists of a front and rear section bolted together with an inner support bolted to the front section. The unit incorporates concentric flanges to which the turbine nozzle vane outer and inner shrouds are bolted. This unit is secured to the rear of the center bearing case. The support also contains nine outlet ducts which transfer the combustion gases from each chamber to the inlet side of the nozzle vanes.

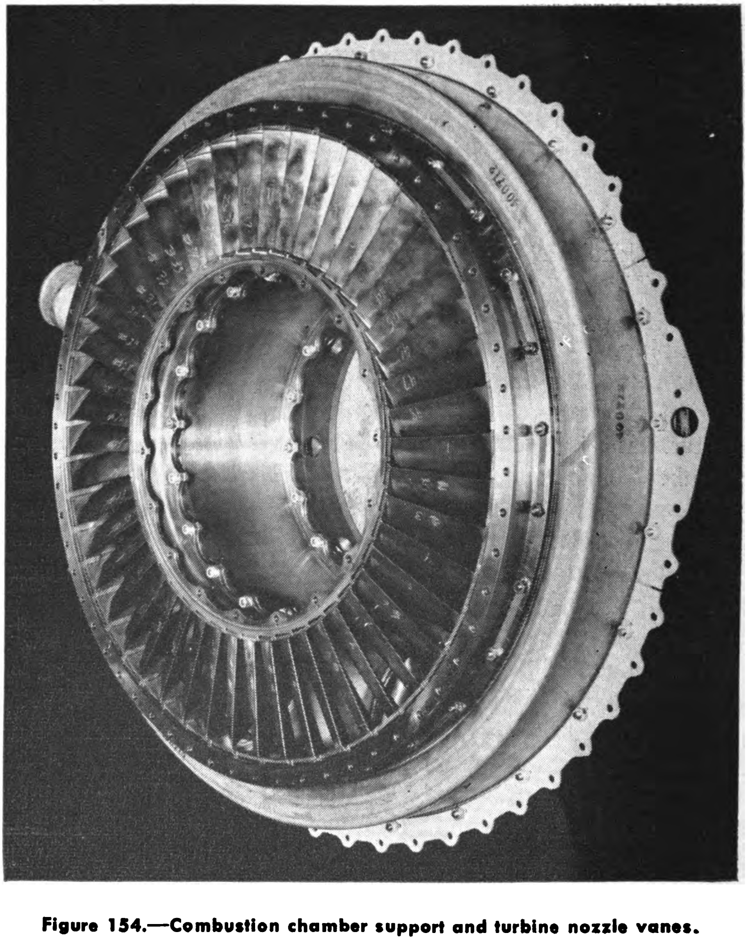


Figure 154.—Combustion chamber support and turbine nozzle vanes.

The air used for cooling the center and rear bearings is passed over the turbine disc and out to the atmosphere through nine outer tubes which connect the support to a collector manifold bolted to the rear of the support.

The nozzle vane assembly is bolted to the rear of the combustion chamber support (fig. 154). This assembly consists of an inner and outer shroud ring and 48 vanes. Platforms, formed at the inner and outer ends of the vanes, are located circumferentially in slots in the inner and outer shroud rings. A tongue is formed at the front of the inner platform of each vane, and is so shaped that the vane is located radially by the engagement of the outer surface of the tongue in a shoulder of the combustion chamber support inner case.

Axial movement of the vane is prevented by the abutment of the front face of the tongue against the shoulder, and by the abutment of the rear face of the tongue against a shoulder on the nozzle vane inner shroud ring. By locating the vanes axially at the front of the inner face only, the possibility of distortion of the turbine air seal, due to vane expansion, is eliminated. An allowance is added to the depth of the slots in the nozzle vane outer shroud ring to permit expansion of the vanes.

The turbine case is secured to the nozzle vane outer shroud ring.

The turbine air seal is mounted on the nozzle vane inner shroud. The three stepped concentric rings on the rear face of the seal overlap the three lands on the front face of the turbine disc to form a seal which prevents the cooling air from escaping and the hot air from traveling down around the disc.

The AIR BAFFLE, which is mounted on the forward mount flange of the center bearing housing, is strengthened by nine equally spaced brackets (fig. 155). The baffle contains holes for allowing the passage of oil feed tubes and oil scavenge tubes to the center bearing case. Its outer profile is scalloped to fit around the inner portion of each combustion chamber. The baffle prevents hot air from the turbine end of the engine being drawn into the rear screen support and the cooling air impeller inlet ports.

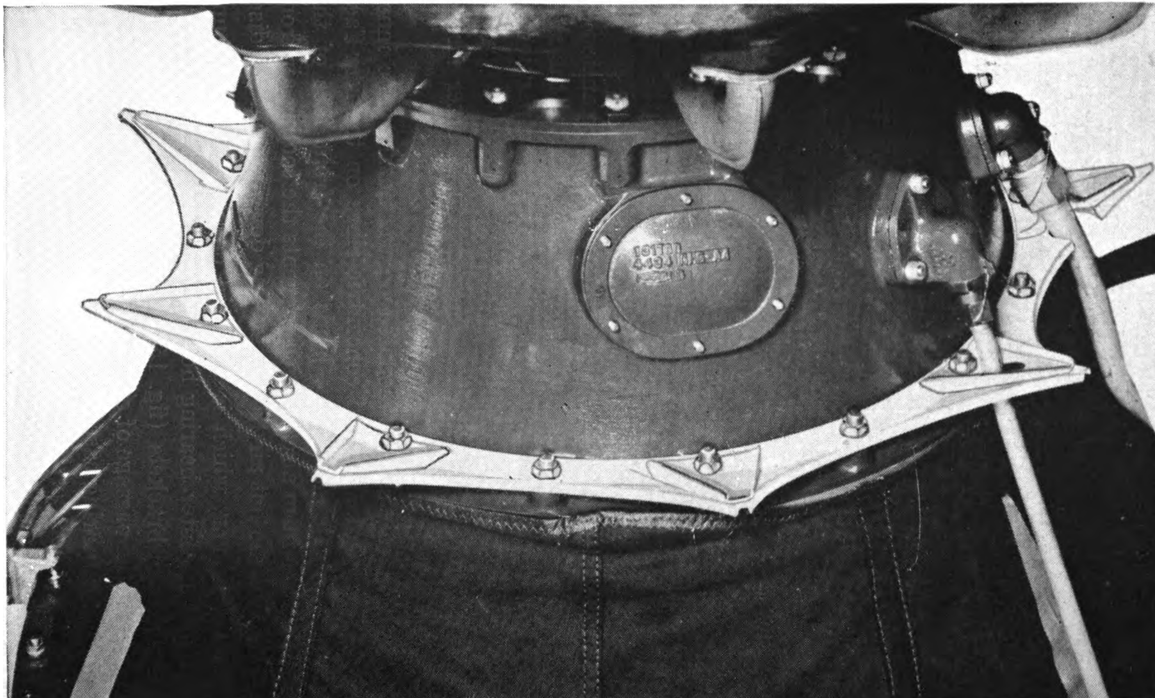


Figure 155.—Air baffle.

The COMPRESSOR and the FRONT and REAR INDUCERS are secured by studs. The compressor has 29 equally spaced radial vanes on each side of a central diaphragm. The inducer vanes are of a conical form to give the correct throat area and are curved over in the direction of rotation to give the correct entering angle.

The front and rear inducers are machined to form a mounting surface for the compressor hub and rear shaft, respectively. The shaft and hub are secured to the compressor by the same studs which secure the inducers. Dynamic balance of the compressor assembly is obtained by means of balancing plugs screwed into the inducer end faces. Figure 156 illustrates the compressor rotor assembly.

The primary function of the COOLING AIR IMPELLER, shown in figure 156, is to cool the center and rear bearings and the front

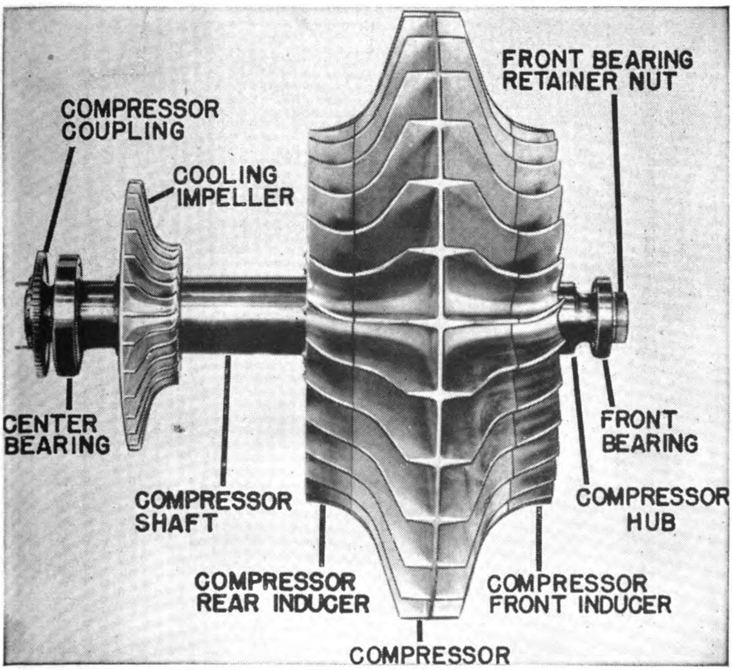


Figure 156.—Compressor rotor assembly.

face of the turbine disc. It is mounted on the compressor shaft, forward of the center bearing. The impeller draws air through separate air intake openings in the rear screen support and delivers air rearward through the center and rear bearing cases. Some of this air passes under the turbine shaft bearing support sleeve and out radially through slots in the flange face contacting the turbine disc. The cooling air passes outward over the turbine disc front face and is then conducted through tubes into a cooling air manifold surrounding the combustion chamber support. From here it is discharged to the atmosphere, as illustrated in figure 157.

Besides cooling the bearings and turbine disc, this pressurized air minimizes gas leakage from the turbine air seal, and oil leakage from the center and rear bearing oil seals.

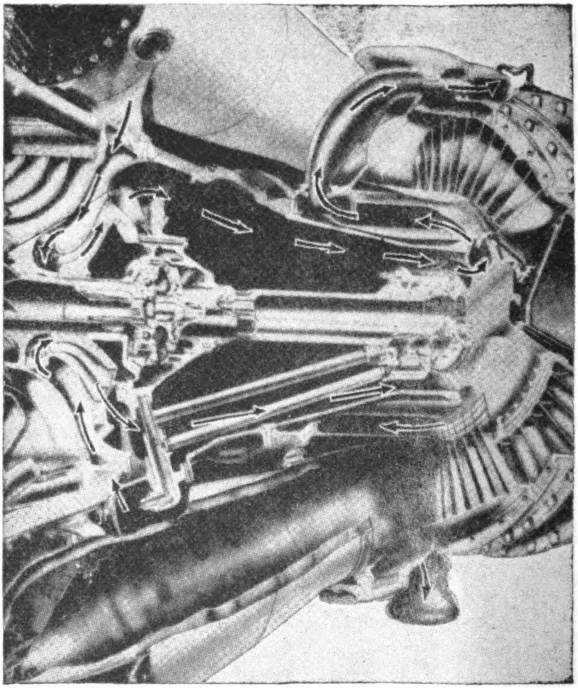


Figure 157.—Cooling air impeller operation.

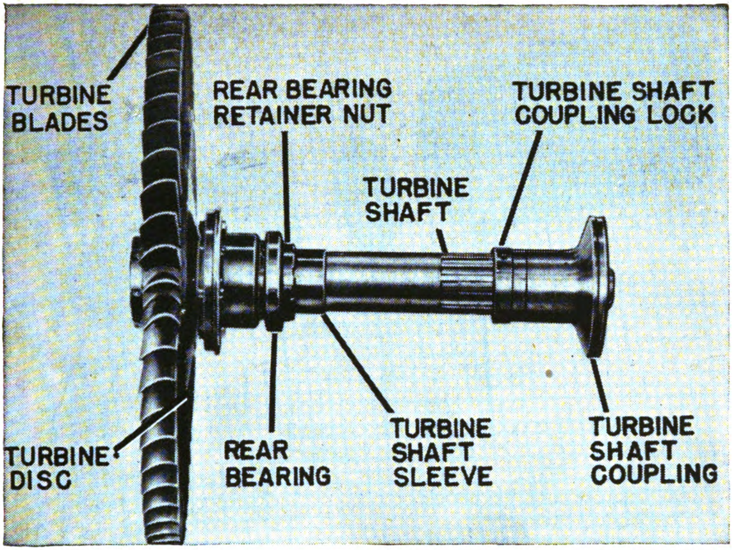


Figure 158.—Turbine rotor assembly.

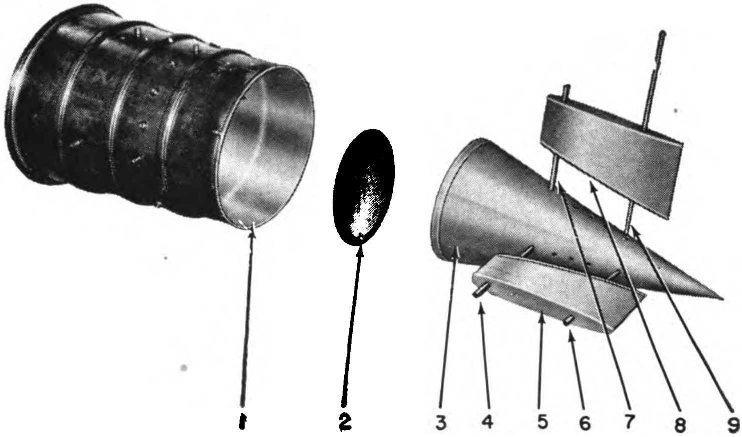
The turbine shaft and turbine shaft sleeve are secured to the turbine disc by means of a gear-type coupling and eight bolts. The periphery of the turbine disc has 54 equally spaced serrated splines to match corresponding serrations on the turbine blades.

The rear bearing is supported on the turbine shaft sleeve. Cooling air passes between the sleeve and the turbine shaft to reduce the bearing temperature.

EXHAUST SECTION

The exhaust section is mounted on the turbine case. This section is composed of the exhaust duct and exhaust cone, as may be seen in figure 159. The cone is supported on four fairings which are positioned by two vertical and two horizontal tierods. The fairings serve to diminish the swirl effect from the exhaust gases after they leave the turbine.

A heatshield, which masks the rear face of the turbine disc, is mounted on the front end of the exhaust cone.



1. Exhaust duct.
2. Exhaust cone heatshield.
3. Exhaust cone.
4. Front horizontal tierod.
5. Horizontal fairing.
6. Rear horizontal tierod.
7. Front vertical tierod.
8. Vertical fairing.
9. Rear vertical tierod.

Figure 159.—Exhaust section.

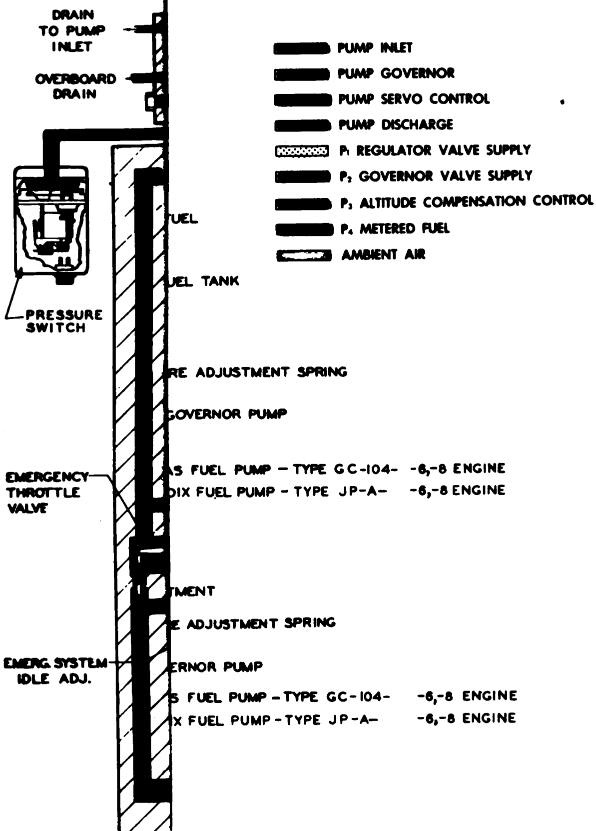
FUEL SYSTEM

The fuel system consists of the following units:

Engine-driven fuel booster pump
Low-pressure fuel filter
Two main fuel pumps
Fuel control unit
Pressure switch
Pressurizing and shut-off valve

A built-in electrical-driven fuel pump is incorporated in the fuel tank.

Fuel under pressure, from the airplane fuel tank pump, is delivered to the engine-driven fuel booster pump mounted on the top of the accessory case. From here it is sent through a low-pressure fuel filter to the two main fuel pumps on the right side of the accessory case. These pumps build up the fuel pressure and send it through a common tube to the fuel control unit, located on the left side of the accessory case.


DRAIN TO PUMP INLET
OVERBOARD DRAIN
PRESSURE SWITCH
EMERGENCY THROTTLE VALVE
EMERG. SYSTEM IDLE ADJ.
PUMP INLET
PUMP GOVERNOR
PUMP SERVO CONTROL
PUMP DISCHARGE
P1 REGULATOR VALVE SUPPLY
P2 GOVERNOR VALVE SUPPLY
P3 ALTITUDE COMPENSATION CONTROL
P4 METERED FUEL
AMBIENT AIR
UEL
UEL TANK
RE ADJUSTMENT SPRING
GOVERNOR PUMP
S FUEL PUMP — TYPE GC-104- -6,-8 ENGINE
DIX FUEL PUMP - TYPE JP-A- -6,-8 ENGINE
TMENT
E ADJUSTMENT SPRING
ERNOR PUMP
S FUEL PUMP - TYPE GC-104- -6,-8 ENGINE
X FUEL PUMP - TYPE JP-A- -6,-8 ENGINE

(Face p. 298)

The fuel, entering the control unit, passes through a high-pressure fuel filter. Then it passes through a solenoid-operated inlet valve that is normally open, thence to the throttle valve. From there the fuel flows to the fuel pressure regulating valve and then into a chamber that is affected by the altitude compensator by means of a diaphragm arrangement. From this compartment it flows through the maximum flow adjustment and then through a double check valve. From there it is delivered through an external tube to the fuel pressure and shut-off valve mounted on the oil sump.

The primary and main fuel manifolds are connected to the fuel pressure and shut-off valve which controls the proportionate fuel distribution between the primary and main fuel manifolds. At low engine speed, the fuel is directed to the primary manifold by the action of the pressurizing valve spring which keeps the valve in a position that prevents fuel flow to the main manifold. At increasing engine speed, the primary fuel pressure increases and overcomes the spring tension which allows fuel to flow to the main fuel manifold as well as the primary. The valve continues to open progressively with increases in engine speed until at maximum engine speed the valve is fully open and the fuel nozzles are receiving the bulk of their supply from the main fuel manifold.

Fuel from the two fuel manifolds is delivered to the fuel nozzles by flexible tubing. In each fuel nozzle, the main fuel flow combines with the primary fuel flow, then discharges from the nozzle orifice into the combustion chamber liner as a finely atomized conical spray.

In an emergency, the fuel system can be manually operated by means of an emergency solenoid valve which, when opened, allows fuel from the main pump to bypass the automatic fuel system of the fuel control unit. The normally open, solenoid-operated fuel inlet valve closes, and the normally closed, solenoid-operated emergency valve opens, allowing the fuel to go through the emergency throttle valve of the fuel control and through the double check valve, then to the fuel pressure and shut-off valve where it is then directed to the main and primary fuel manifolds.

The lubrication system (fig. 161) is a self-contained, high-pressure, wet sump system. It contains pressure oil feeds to the three main bearings and to the accessory drives. The oil is of low viscosity and is antifreezing. The bulk of the oil is contained in a sump attached to the underside of the accessory case. The oil sump contains a two-stage oil pump, three oil strainers, a de-aerator tray, and provides mounting bosses for the pressure oil gage and temperature connections.

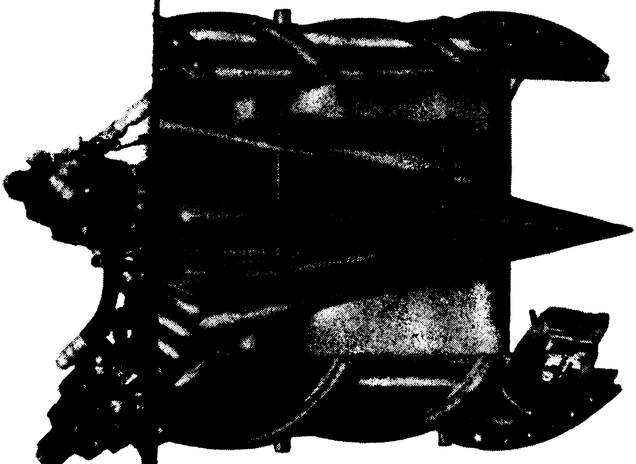
For clarity of description, the pressure oil system will be divided into four branches.

In the FIRST BRANCH, oil is drawn from the sump through a strainer by the pressure oil pump, which forms the lower half of the dual pump unit. From the pressure oil pump, the oil passes through the high-pressure oil strainer to a junction located behind a plug on the left side of the sump. Through cored passages in the accessory case, oil is supplied immediately to the upper and lower fuel pump drives. A check valve, located in the cored passage, prevents any seepage of fuel from the fuel pumps into the oil system.

In the SECOND BRANCH, oil from the junction behind the plug passes through a cored passage in the sump to the pressure oil gage connection.

In the THIRD BRANCH, oil from the junction behind the plug passes through a series of cored passages in the sump and accessory case. One of the passages carries oil to the pressure oil relief valve. A second passage provides lubrication to the fuel control unit drive, the auxiliary drive, and through an oil nozzle to the auxiliary fuel booster pump drive. Splash oil lubricates the starter, the generator, and the take-off drives. A third passage carries oil to an oil nozzle located in the accessory case cover for lubrication of the accessory drive pinion and bearings. A fourth passage carries oil through an oil tube to an oil nozzle located in the front bearing housing for lubrication of the front bearing.

In the FOURTH BRANCH, oil from the large annulus passes through internally cored passages and a series of external and internal oil tubes to the oil nozzle in the center bearing sup-



PRESSURE OIL
PRESSURE PUMP INLET OIL
SCAVENGE OIL
PRESSURIZING AIR

(Face p. 300)

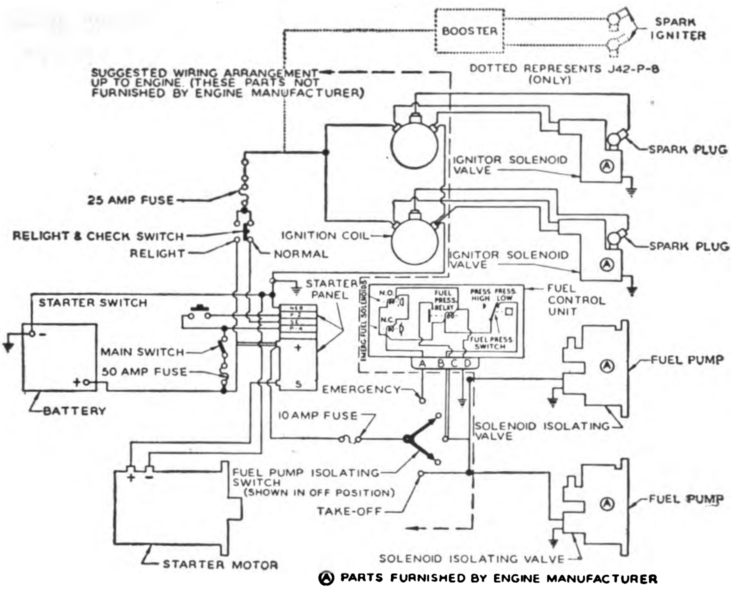


Figure 162.—Electrical system.

port for lubrication of the center bearing, and to an oil nozzle in the rear bearing cover for lubrication of the rear bearing.

ELECTRICAL SYSTEM

The engine starting system includes two igniters, and a starter furnished by the purchaser (GFE). The aircraft starting equipment consists of a unit or units to supply current to the igniters and to the starter.

COOLANT INJECTION SYSTEM

The engines are equipped with a coolant injection system, the operation of which causes an increase in thrust. The equipment consists of two slingers which are secured to the front and rear sides of the compressor rotor and two manifold assemblies secured to the front bearing housing and rear air inlet fairing, respectively. A common coolant inlet connection for the two manifolds is mounted on an adaptor on the upper

right side of the compressor case. The coolant injection mixture is injected into the air stream as it enters the compressor front and rear inducers.

PRINCIPLES OF OPERATION

A knowledge of the principles of operation and the important performance differences between the turbo-jet and the conventional piston engine may help one in visualizing problems of operation and repair.

In sequence, air enters the turbo-jet engine, is compressed, heated, partially expanded through a turbine to drive the compressor, and subsequently expanded through an exit nozzle to produce a high-velocity jet. The acceleration imparted to the mass air in passing through the engine (measured by the product of the mass rate of air flow and the difference between leaving and entering velocities) represents the force, or thrust, reacting on the engine and airplane. Where a propeller derives its thrust from imparting a small acceleration to a large mass of air, the jet engine imparts a great acceleration to a small mass of air.

As airspeed increases from zero, the thrust of the turbo-jet decreases some 10 or 15 percent around 200 to 400 miles per hour and then increases, equaling its static rating near 600 to 800 miles per hour. The variations being small, this engine can be considered essentially a constant thrust engine. The piston-propeller engine is, essentially, a constant horsepower engine. This means further that the jet engine horsepower increases almost directly as airplane velocity, while the piston engine thrust drops off continually from the static value as airspeed is increased.

A jet propelled aircraft is usually a high-speed craft, since the faster it goes the greater the power the engine makes available, while the propeller engine power remains constant. The jet propelled aircraft, then, is extremely sensitive to drag changes since any drag item represents a huge power requirement at high speed. The jet aircraft usually has a higher airspeed for best rate of climb than the propeller-driven aircraft.

QUIZ

1. What is the purpose of the deep groove ball bearing in addition to supporting the radial load of the rotor assembly?
2. In which combustion chambers are igniters incorporated?
3. What are the two stages of spray combined in each fuel nozzle?
4. Under what condition is all fuel delivered to the primary atomizer of the fuel nozzle?
5. When is the current to the igniters cut off?
6. What is the primary function of the cooling air impeller?
7. In case of emergency, the solenoid valve allows fuel to bypass a unit. What is the unit?
8. What method of oil lubrication is used for the starter, the generator, and the take-off drives?
9. How many igniters are included in the engine starting system?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

POWER

1. Reciprocating and turbo-jet.
2. Work per unit of time.
3. Horsepower.
4. 2,376,000 ft.-lbs.
5. Approximately 9.4 hp.
6. Approximately 91.6 hp.
7. Near the end of the power stroke.
8. Shortly before the piston reaches the top of the compression stroke.
9. One.
10. 7:1.

CHAPTER 2

ENGINE PARTS

1. Tulip, semi-tulip, and mushroom.
2. Exhaust valve.
3. Prevent leakage of gas pressure and reduce seepage of oil to a minimum.
4. Crankshaft.
5. Planetary.
6. Bell, sun, and planetary.
7. Aluminum alloy.
8. Full-floating.
9. Connecting rod.
10. To compress the fuel-air mixture delivered to the combustion chamber.

CHAPTER 3

IGNITION SYSTEMS

1. By connecting a condenser in parallel with the breaker points.
2. Primary Circuit
   - b. breaker points
   - e. control switch
   - f. coil with 150 windings
   - h. primary condenser

   Secondary Circuit
   - a. spark plugs
   - c. high-tension cable
   - d. distributor rotor
   - g. distributor block electrodes
   - i. coil with 1,500 windings
3. It causes a rapid collapse of the primary magnetic field.
4. To compensate for the top-dead-center variations of each piston caused by the elliptical travel of the knuckle pins on the articulating rods.
5. The setting of the engine magnetos so that the spark plugs in a cylinder fire simultaneously.
6. To provide a source of external high-tension current during starting periods.
7. Preignition.
8. Long-core.
9. Double magneto, base-mounted, for 18 cylinders, left rotating, Edison-Splitdorf, model or modification 2.

CHAPTER 4

ENGINE ACCESSORIES

1. *Aircraft Fuel Systems*, NavPers 10335.
2. Inertia.
3. A property of matter which causes a body at rest to tend to stay at rest and a body in motion to continue in motion unless acted upon by some external force.
4. Electric inertia, electric inertia with direct cranking, and direct electric starters.
5. It cranks the flywheel until it is rotating at high speed, then engages the flywheel with the engine starter jaw through a train of gears and a multiple-disc clutch.
6. Instead of the hand crank to energize the flywheel, the electric inertia starter incorporates an electric accelerating motor.
7. They are the simplest type of charging source for the aircraft batteries.
8. By increasing its speed.
9. Production of heat beyond a safe limit.

CHAPTER 5

LUBRICATION AND COOLING

1. Excess oil will foul the spark plugs, and produce excessive carbon deposit on cylinder heads and pistons.
2. Engine oil is diluted by allowing a small amount of fuel to enter the oil inlet line. This is done before the engine is stopped in cold weather. Diluting the oil makes the engine easier to start in cold weather.
3. Inadequate cooling.
4. To measure cylinder head temperature.
5. Dry sump.
6. Oil pressure pump and oil scavenger pump.
7. Oil pressure relieve valve.
8. Strainers and filters.
9. Bourdon.
10. Air-cooled.

CHAPTER 6

PRATT & WHITNEY TWIN WASP (R–1830) ENGINE

1. On pads attached to the exterior of the front case.
2. By adjusting the position of two pairs of spark advance pinions.
3. Three.
4. No. 5 and No. 12.
5. By the blower case.
6. It discharges any fuel that may be accumulated while the engine is being started.
7. Rear oil pump.
8. 85 to 100 p.s.i.
9. By oil under pressure which is carried through the two crankpins to the bearings via drilled passages in the crankshaft.
10. On the No. 8 cylinder head.

CHAPTER 7

PRATT & WHITNEY DOUBLE WASP (R–2800) ENGINE

1. 20:9. Spur planetary type.
2. It makes possible the accurate measurement of the actual power output to the propeller when the airplane is in flight.

3. On external pads on the front accessory case.
4. In the front support plate.
5. On the front accessory case.
6. Machined from three steel forgings.
7. No. 8 and No. 9.
8. Double-track, four-lobe.
9. Seven.

CHAPTER 8

WRIGHT CYCLONE (R–3350) ENGINE

1. Around the rear circumference of the crankcase front section rear half. The magneto is mounted on the top center of the supercharger rear housing cover.
2. A gear-type booster pump.
3. AN 60.
4. It is of the two-row, split-clamp type, in three sections hollow throughout their length.
5. By a movable bronze counterweight attached to the front crank cheek.
6. Full-trunk type with recesses in the head for intake and exhaust valve clearance.
7. On the upper right and left positions of the supercharger rear housing cover. Counterclockwise.
8. Full pressure, dry-sump type.
9. Magneto, main conduit, low-tension harness, induction coils, high-tension leads, and spark plugs.

CHAPTER 9

PRATT & WHITNEY (R–4360) ENGINE

1. Four-row radial, air-cooled, with 28 cylinders.
2. Propeller shaft and its thrust bearing, the propeller governor and front oil pump drives, and the front oil pump.
3. Fifty-six.
4. On the front crankcase.
5. Regulates the timing of the magneto drive system.
6. Each cam is driven by two cam reduction gear and pinion assemblies at one-sixth the speed of the crankshaft.
7. Hollow, one-piece assembly. Five.

8. Fully intersected, partially intersected, and non-intersected types, according to the extent or absence of the cutouts providing clearance for the master rod bolts.
9. Stellite.
10. No. 3, No. 4, and No. 5 cylinder banks.
11. By the spiral gears of the fuel pump and magneto pump drive shafts.
12. Scintilla D4RN-2. Seven.
13. To prevent flashover at high altitudes.
14. No. Exhaust valve.

CHAPTER 10

THE TURBO-JET ENGINE

1. Rockets, ram jet, aeropulse, and turbo-jet.
2. The rocket carries oxygen as well as fuel.
3. Inlet duct, rotary air compressor, combustion chambers, turbine, and exhaust section.
4. Outer casing, flame tube, and burner nozzle.
5. Eliminate turbulence in the emerging jet.
6. None.
7. It drives the air compressor and necessary auxiliary equipment.
8. They join adjacent combustion chambers.
9. An impeller of large diameter and a high speed of rotation is necessary, resulting in a high linear speed at the periphery.

CHAPTER 11

T-40 TURBO-PROP ENGINES

1. To direct the air through the compressor blades and to prevent the entrance of large foreign objects.
2. They hold the vane assemblies in place.
3. Dome assembly.
4. Turbine unit assembly.
5. Front inner liners.
6. Turbine support, turbine rotor assembly, and turbine casing assembly.
7. Cooled by air which circulates through the annulus formed by the support and a surrounding air seal shroud.
8. Exhaust system.

9. On the front face of the assembly.
10. It prevents oil in the system from draining back through the pump when the power section is shut down.

CHAPTER 12

J33 TURBO–JET ENGINE

1. Dual-inlet centrifugal type.
2. Constant displacement.
3. On the front of the unit.
4. It drains the fuel manifold of all fuel when fuel pressure within the manifold is below 5 p.s.i.
5. Wet sump.
6. Eight.
7. To improve thrust rating at low altitudes.
8. Into the compressor air inlet.

CHAPTER 13

J34 TURBO–JET ENGINE

1. Axial flow.
2. Momentary closing of the control timer switch energizes the control timer. The control timer closes and maintains the electrical circuits to the starter motor and ignition coils for 30 seconds. The starter solenoid contactor closes the circuit to the starter motor when the solenoid coil is energized by the action of the control timer. The starter, when energized, accelerates the engine rotor to a speed sufficient to give self-sustained operation of the engine. The ignition coils supply high voltage for ignition. The spark plugs ignite the fuel-air mixture.
3. Four-piece unit.
4. Two.
5. In the combustion chamber section.

CHAPTER 14

J42 TURBO-JET ENGINE

1. Supports axial thrust.
2. No. 3 and No. 8.
3. Primary and main.
4. At low fuel flow.
5. After the engine has been started.
6. To cool the center and rear bearings and the front face of the turbine disc.
7. Fuel control unit.
8. Splash.
9. Two.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

AVIATION MACHINIST'S MATES (AD)

RATING CODE NO. 730

General Service Rating

Aviation machinist's mates maintain, repair, test, inspect, adjust, and install aircraft engines (reciprocating and turbine) and accessories, including propellers, carburetors, pumps, oil coolers, and associated equipment. Operate engines and auxiliary power plants for operational or test purposes as may be appropriate.

Emergency Service Ratings

Title	Abbr.	Rating Code No.	Definition
Aviation Machinist's Mates E	ADE	731	Repair, install, and maintain aircraft engines and accessories.
Aviation Machinist's Mates F	ADF	732	Maintain aircraft engines and accessories and operate the power plants as flight mechanics (engineers).
Aviation Machinist's Mates P	ADP	733	Maintain and repair aircraft propellers.
Aviation Machinist's Mates G	ADG	734	Maintain and repair aircraft carburetors.

Naval Job Classifications

Group code nos.	Group titles	General service	Emergency service			
		AD	ADE	ADF	ADP	ADG
50000–50099	Flight engineers	X		X		
50100–50199	Aviation flight mechanics—gunner	X		X		
51400–51499	Carrier service personnel	X	X			
51500–51599	Airport service personnel	X	X	X		
52100–52199	Aircraft engineering technicians	X	X			
52200–52299	Aircraft maintenance supervisors	X	X			
52300–52399	Aircraft power plant mechanics	X	X	X		
52400–52499	Aircraft engine mechanics, overhaul	X	X			
52500–52599	Aircraft line maintenance mechanics	X	X			
52900–52999	Aircraft mechanics, basic	X	X	X	X	X
53100–53199	Airplane propeller mechanics	X			X	
53200–53299	Airplane carburetor mechanics	X				X
53500–53599	Airplane accessory repairmen, miscellaneous	X	X			
59300–59399	Aircraft salvage technicians	X	X		X	X

Qualifications for advancement in rating	AD 730	ADE 731	ADF 732	ADP 733	ADG 734
XXX .100 PRACTICAL FACTORS					
.101 TOOLS					
Use common hand tools in maintaining and repairing aircraft engines and accessories.	3, 2, 1, C	3, 2, 1, C	3, 2, C	3, 2, 1, C	3, 2, 1, C
Use shop power-driven tools, including drill press, bench grinder, etc.	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
.102 MEASURING INSTRUMENTS					
Use measuring instruments in maintaining and repairing aircraft engines and accessories.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.103 BLUEPRINTS					
Read simple blueprints and wiring diagrams.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Read and work from blueprints and wiring diagrams.	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
Make sketch for engine or engine accessory repair.	1, C	1, C	1, C	1, C	1, C
.104 AIRPLANE HANDLING					
Handle and service (including fueling) aircraft on the ground or deck in accordance with local and general approved practices. Load and stow equipment. Secure aircraft by tying down and mooring. Undertake the responsibilities of plane captain to insure general readiness of aircraft. Make daily and pre-flight inspections. Clean windshields, enclosures, and surfaces.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.105 ENGINES					
Service, maintain, install, and repair engines. Perform routine checks in accordance with approved procedures. Remove, clean, test, and replace spark plugs and/or turbine nozzles. Start, warm up, and stop engines; perform checks to discover malfunctions.	3, 2, 1, C	3, 2, 1, C	2, 1, C	3, 2, 1, C	
Adjust valve clearance; time the magnetos, and make compression checks. Make engine changes.	2, 1, C	3, 2, 1, C	1, C		

Qualifications for advancement in rating	Applicable rates				
	AD	ADE	ADF	ADP	ADG
	730	731	732	733	734
Prepare engines for short-time storage. Remove engines from storage by cleaning and assembly.	1, C	1, C			
.106 PROPELLERS					
Check balance, pitch, and track of propellers. Remove, service, and install propellers and check their operation. Install and adjust governors.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	
Remove, check, clean, repair, and install dome assemblies, relays, distributor valves, and governors. Perform magnaflux tests.	2, 1, C			2, 1, C	
Repair propellers and propeller accessories.	1, C			1, C	
.107 CARBURETORS AND FUEL SYSTEM					
Check carburetors and fuel system for proper operation. Trace fuel lines; clean strainers; check valves and fuel cells for leaks or sediments.	3, 2, 1, C	3, 2, 1, C	2, 1, C		3, 2, 1, C
Remove, disassemble, clean, inspect, assemble, perform upkeep on, and install carburetors.	2, 1, C	1, C	1, C		3, 2, 1, C
Set up, operate, and maintain carburetor flow benches. Test flow, pressure, and satisfactory operation of carburetors and water injection system.	1, C				2, 1, C
.108 INSTRUMENTS AND ACCESSORIES					
Remove, service, and install pumps, magnetos, ignition coils, distributors, starters, generators, batteries, oil coolers, and other power plant accessories, including control panel, flight, and engine instruments.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.109 OPERATION					
If assigned to activities requiring flight engineers, perform the following:					
Follow proper engineering procedure and take necessary action in inspecting, testing, and operating engines, controls, and equipment on own planes before flight and in	2, 1, C		2, 1, C		

Qualifications for advancement in rating	Applicable rates				
	AD	ADE	ADF	ADP	ADG
	730	731	732	733	734
taxiing, take-off, and climb. Set controls for fuel system, mixture control, carburetor supercharge, oil system, generator, auxiliary power plant, electric power circuits, and cowl flaps, in accordance with procedure prescribed by squadron to which attached. Use power chart for engines used in planes of squadron to which attached. Construct and use simple "Howgoesit" curves. Recognize specific signs of malfunctioning of engines from observations of instruments and, when possible, make adjustments in flight. Follow prescribed squadron engineering procedure and take necessary action in descent, landing, and stopping.					
.110 SAFETY PRECAUTIONS					
Observe local and general safety precautions for shop and line maintenance, fueling, servicing, and operation of aircraft.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.111 RECORDS AND REPORTS					
Keep records and prepare reports applicable to servicing, operating, and repairing aircraft engines and accessories.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.112 SUPERVISION					
Supervise and train personnel engaged in servicing and repairing the following:					
Aircraft engines and accessories	1, C	1, C			
Propellers	1, C			1, C	
Carburetors	1, C				1, C
Organize and administer repair facilities for aircraft engines and accessories.	C	C		C	C
XXX .200 EXAMINATION SUBJECTS					
.201 TOOLS AND MEASURING INSTRUMENTS					
Names and uses of common hand tools and measuring instruments used for engine and accessory maintenance and repair.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C

Qualifications for advancement in rating	Applicable rates				
	AD	ADE	ADF	ADP	ADG
	730	731	732	733	734
.202 AIRPLANE HANDLING AND CHECKING					
Proper methods of handling aircraft on the ground, on deck, or in the water, in accordance with local and general approved practices. Methods used to secure aircraft by tying down and mooring; methods used to load and stow equipment. Procedures for starting, warming up, testing, and stopping aircraft engines. Procedure for checking engines and accessories for malfunctioning. Method of cleaning aircraft surfaces, enclosures, windshields, and engine and accessory parts and the proper materials to be used.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.203 ENGINES					
Theory of operation and construction of engines, including make-up of parts and function of each, dividing engine operation into the systems of power transmission, cooling, carburetion, lubrication, and ignition.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Prepare diagrammatic sketches of aircraft power plant systems.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C		
Procedures for servicing, maintaining, and repairing engines, including inspection, tests, and routine servicing. The general pressure, temperature, and r.p.m. limitations for commonly used engines and the specific limitations of engines of own activity for warm-ups and cruising.	2, 1, C	2, 1, C	1, C		
Procedures for adjusting valve clearance, timing magnetos, and making compression tests.	2, 1, C		2, 1, C		
Operation of engines and auxiliary power plants for take-off, climb, and cruising under various loading and operational conditions. Use of "Howgoesit" curves and power curves.					

Qualifications for advancement in rating	Applicable rates				
	AD	ADE	ADF	ADP	ADG
	730	731	732	733	734
.204 PROPELLERS					
Hydraulic and electrical principles applied to propellers; theory of operation, procedures for servicing, and nomenclature of propellers and propeller accessories.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Testing and adjusting procedures for propellers and propeller accessories. Procedures for heat-treating, straightening, and testing strength of materials.	1, C			2, 1, C	
Assembly and disassembly procedures and preparation for storage of propellers.	C			1, C	
.205 CARBURETORS AND FUEL SYSTEM					
Procedures for checking and servicing aircraft carburetors and fuel system. Theory of operation, nomenclature of parts, and manner of inspecting, cleaning, and installing parts. System of marking carburetors and fuel system lines.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Testing of carburetors on a flow bench and adjusting for operation. Materials and parts likely to be faulty and the reasons.	1, C	C			2, 1, C
.206 INSTRUMENTS AND ACCESSORIES					
Nomenclature, installing and servicing procedures, and theory of operation of aircraft engine accessories and instruments.	3, 2 ,1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.207 MATHEMATICS					
Basic mathematics, including the following:					
Arithmetic, measurement, and graphs.	3, 2, 1, C	3, 2, 1, C	3. 2, 1, C	3, 2, 1, C	3. 2, 1, C
Elementary algebra, trigonometry, and geometry.	1, C	1, C	2, 1, C	2, 1, C	2, 1, C
Solve problems pertaining to:					
Aircraft maintenance and fueling.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Aircraft loading, weight, and balance.	2, 1, C	1, C	2, 1, C		

Qualifications for advancement in rating	Applicable rates				
	AD	ADE	ADF	ADP	ADG
	730	731	732	733	734
.208 AIRCRAFT CONSTRUCTION					
Basic principles of the theory of flight and the principles of aircraft construction, including the rigging of controls, the general types of construction encountered in the fuselage, wings, empennage, and landing gears, and the layout of the hydraulic and electrical systems. Alignment and adjustment of control surfaces, with emphasis on adjustment of tabs. Basic principles of weight and balance of aircraft.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.209 FLIGHT OPERATIONS					
General duties of air crew members, including knowledge of interplane communications, crew stations, and procedures for abandoning plane, and for fire, crash, General Quarters, and search stations. The use of armament, pyrotechnics, and survival equipment employed in aircraft operations.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.210 SAFETY PRECAUTIONS					
Local and general safety precautions for shop and line maintenance, fueling, servicing, and operation of aircraft. Procedure for safety wiring and bonding.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.211 RECORDS AND REPORTS					
Engineering records to be kept and reports to be made for maintaining, servicing, and operating aircraft.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.212 PUBLICATIONS					
General content and use of technical bulletins, publications, and catalogs pertaining to aircraft maintenance and repair.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.213 ORGANIZATION					
Organization of own unit.	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Organization of own squadron or air department and relationship of other ratings to the Engineering Department.	1, C	1, C	1, C	1, C	1, C

XXX .300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE

Aviation machinist's mates advance to Warrant MACHINIST 7411 (Aviation Machinist). They act as Assistant Engineering Officers in the Air Department.

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